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FISH AND WILDLIFE SERVICE
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THE PROGRESSIVE FISH-CULTURIST

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THE DISTRIBUTION OF FOUR ANADROMOUS MEMBERS OF THE GENUS *SALMO* IN THE NORTHERN HEMISPHERE

James E. Mason
U. S. Fish and Wildlife Service
Orono, Maine

THE FOUR ANADROMOUS MEMBERS of the genus Salmo that are of noteworthy importance to commercial or sport fishing are the Atlantic salmon, Salmo salar salar Linnaeus; the sea trout, Salmo trutta Linnaeus; the steelhead trout, Salmo gairdnerii Richardson; and the sea-run cutthroat trout, Salmo clarkii Richardson. In their original distributions, as indicated in the references listed at the end of this paper, they were confined to the northern hemisphere: the cutthroat, steelhead, and Atlantic salmon in North America, and the sea trout and Atlantic salmon in European and North Atlantic waters, as shown in figures 1 and 2. Efforts to transplant the anadromous varieties of this genus in the northern hemisphere have met with little success except for the introduction of sea trout near Orland, Maine, although landlocked varieties have been transplanted successfully in both hemispheres.

The southern limits of the fresh-water ranges are fairly well recorded in the literature, but it is probable that the northern limits of all species exceed those shown in figures 1 and 2. The ocean ranges are not adequately known for any of the species.

The steelhead and the cutthroat spawn principally in the spring, when temperatures are rising; whereas the sea trout and the Atlantic salmon spawn in the fall, when temperatures are dropping. The salmon and the sea trout generally ascend the rivers in the spring, although these fish may ascend in the summer and fall. The cutthroat commonly enters fresh water in the fall and winter; whereas the steelhead may enter at any time of the year, the peak migrations occurring in April and August.

The life histories of the fish are such that the environment might control their distribution in either fresh or salt water, or both. It would seem logical to conclude that fresh-water distribution would be limited by spawning, egg development and hatching conditions, and nursery and rearing environment for the young, rather than by such limitations of the rivers as migration paths (assuming adequate flow, no obstructions, and minimum predation). Survival in salt water would be limited primarily by availability of food and by predation.

Mean air and sea temperatures are used in this paper as broad indices of the environmental limitations to the distribution of the four species. The air temperatures are used as indicators of fresh-water temperatures. Figure 1 illustrates the annual temperature extremes, using February data for winter minima and August data for summer maxima. Figure 2 illustrates the sea and air temperatures for May and November. Table 1 is a summary of the data on temperature relationships derived from the two figures.

DISCUSSION

Table 1 shows that all species are capable of living at temperatures ranging upward from about 32° F. in fresh water. The cutthroat generally ranges in colder waters than the others. The sea trout and salmon have virtually the same range, with that of the salmon extending into somewhat warmer and colder extremes. The steelhead ranges into warmer water than the other species.

Air and sea temperatures of the eastern Atlantic Ocean areas approximately correspond to those of the northeastern United States and eastern Canada but at higher latitudes. A similar picture is found in the Pacific. Certain of the marine, migration season, and spawning season temperatures for the northeastern United States are somewhat lower than those of Europe. They may be the limiting factor in the production of sea trout in the State of Maine.

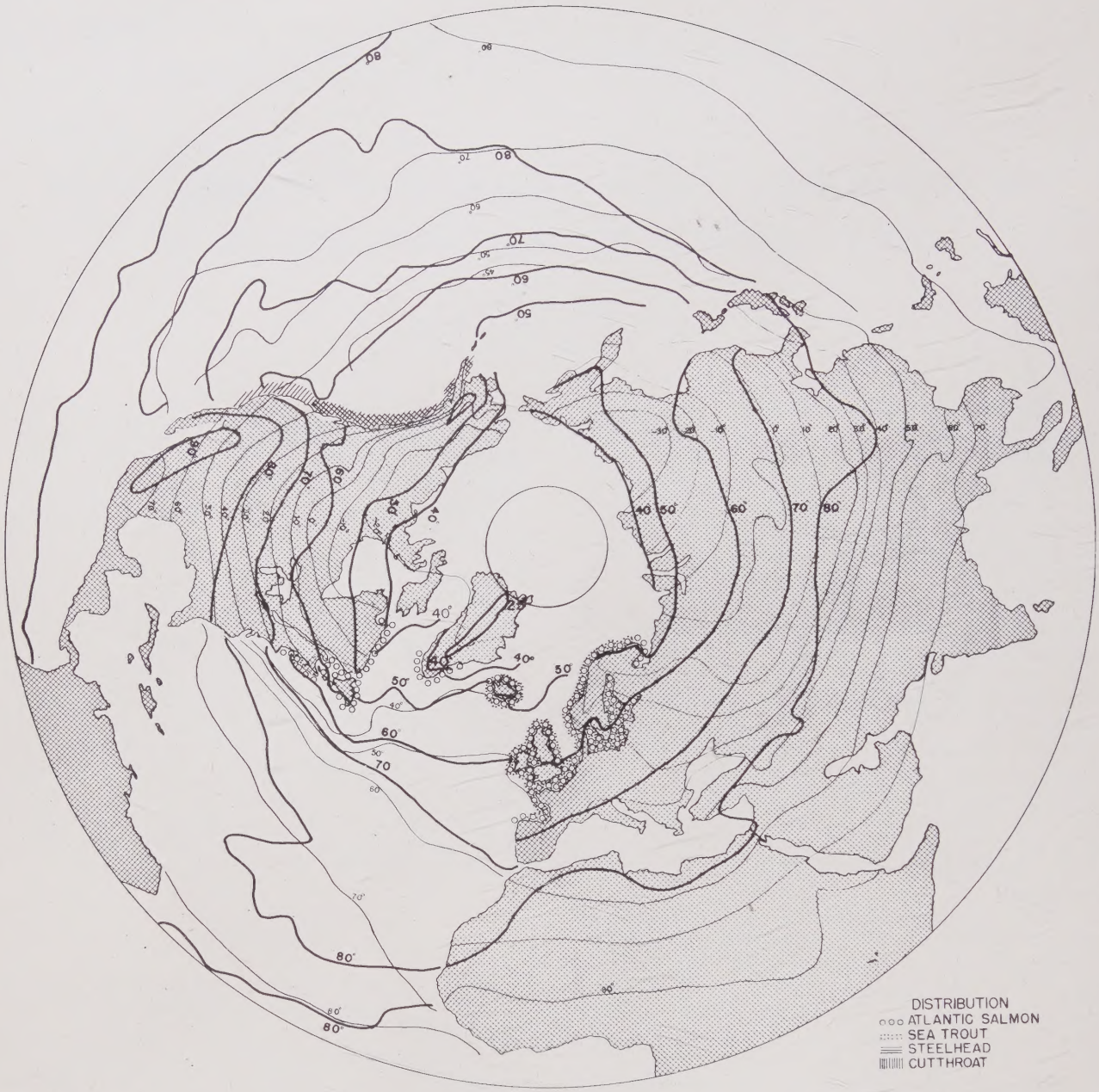

FIGURE 1.--Distribution of genus Salmo and mean temperature (°F.) isotherms for the months of February (——) and August (═══). Temperatures over land masses are air temperatures corrected to sea level, and those for the oceans are for the sea surface. Thermal data from Napier Shaw, courtesy of Cambridge University Press.

Annual extreme temperatures indicate favorable conditions for the four Salmo from the northern part of Japan into the Kamchatka peninsula and along the Asiatic coast between these latitudes. In addition, marine and air temperatures appear favorable during the spring migration season of Atlantic salmon and sea trout. However, apparently favorable temperatures are found only south of Japan during the normal spawning season of the two species. The data indicate that Atlantic salmon and sea trout could not be introduced successfully into western North Pacific waters.

There is no readily apparent reason, from the thermal data, why steelhead and cutthroat trout should not be found from northern Japan into the Kamchatka peninsula. Salmo mykiss,

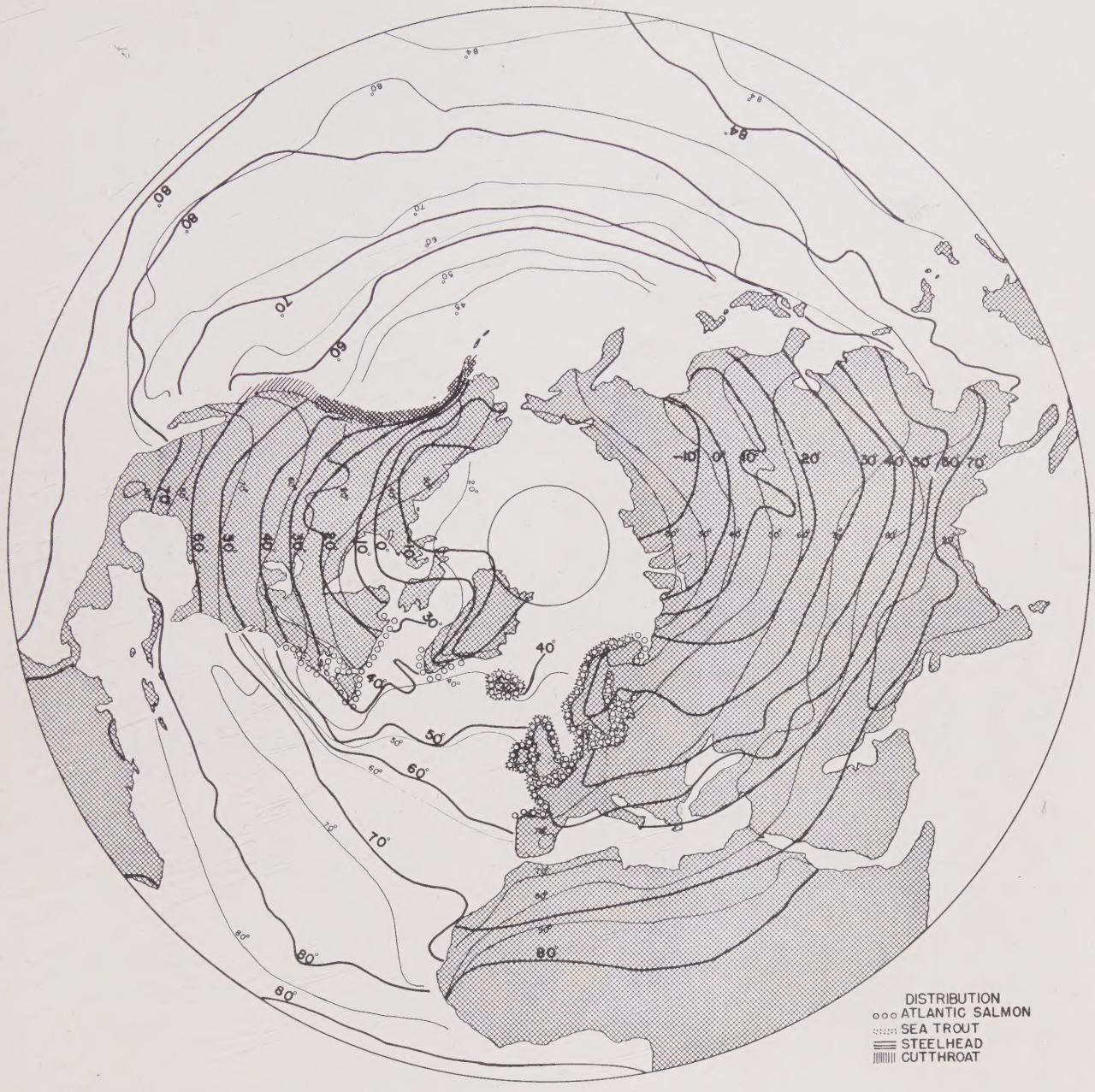

FIGURE 2.--Distribution of genus Salmo and mean temperature (°F.) isotherms for the months of May (——) and November (——). Temperatures over land masses are air temperatures corrected to sea level, and those for the oceans are for the sea surface. Thermal data from Napier Shaw, courtesy of Cambridge University Press.

closely related to the cutthroat, has been recorded in that range.

SUMMARY

Air and sea surface temperatures were used as broad indices of the environmental limitations of the distribution of the Atlantic salmon, sea trout, steelhead, and cutthroat. The temperature data were briefly examined as maxima and minima over the ranges of the species and as seasonal temperatures affecting migration into fresh water and spawning.

All four species utilize approximately the same range of temperatures in comparable phases of their life histories, with the steelhead appearing in warmer extremes and

TABLE 1.--Approximate air and sea temperatures (°F.) throughout the ranges of the species of the genus Salmo in relation to certain phases of their life histories

/Temperatures higher and lower than those directly readable from the isotherms of figures 1 and 2 are followed by a plus (+) and minus (-), respectively./

Species and locality	Annual extremes				Season of migration into fresh water[1]				Spawning season air extremes[2]	
	Air		Marine coastal		Air		Marine coastal			
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Steelhead trout: all	80-	0	60+	45-	60+ [3]80-	40 [3]55	60- [3]60+	45- [3]50	60+	40-
Cutthroat trout: all	70-	0	60	45-	[4]50- [5]40	[4]10 [5]0	[4]60- [5]50-	.. [5]45-	60-	40
Atlantic salmon:										
North America	70-	-10	60+	40-	50+	30-	40+	40-	40	10+
Europe	70-	10-	60+	50-	60	30	60-	40-	50	20
Sea trout:										
Maine	70-	20	60	40-	50	50	40	40	40	40
Europe	70-	10-	70-	40-	60	40-	60-	40-	50	20

[1]Temperatures for May except where noted.
[2]May temperatures for steelhead and cutthroat trout; November for Atlantic salmon and sea trout.
[3]Temperatures for August. [4]Temperatures for November. [5]Temperatures for February.

the cutthroat in colder extremes. The ranges of the Atlantic salmon and sea trout overlap, with the salmon range extending farther north and south.

Relatively low temperatures may be the limiting factor in the production of sea trout introduced at Orland, Maine.

The data indicate that Atlantic salmon and sea trout could not be introduced successfully into the waters of the western North Pacific Ocean. Favorable temperatures for steelhead and cutthroat appear to lie between northern Japan and the Kamchatka peninsula. A related cutthroat species is recorded for that range.

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IS THIS A RECORD FOR MOVING FISH?

On December 29, 1952, five fish-culturists at the U. S. Fish-Cultural Station at Marion, Alabama, moved 804,000 bluegill fingerlings (weight, 1,192.4 pounds) from a 17.1-acre pond within 8 hours. The operation included removing the fish from the brood pond, transporting them to the holding house, grading them, weighing them, and placing them in holding ponds.

It should be noted that the poundage removed did not constitute the entire production of this pond.

MIGRATORY TENDENCIES OF THE MANCHESTER (IOWA) STRAIN OF RAINBOW TROUT

H. M. Ratledge and J. H. Cornell
North Carolina Wildlife Resources Commission
Raleigh, North Carolina

COOPERATING WITH THE U. S. Fish and Wildlife Service, North Carolina conducted studies on the migratory tendencies of the Manchester (Iowa) strain of rainbow trout during the 1952 fishing season. The rainbow trout propagated at the Manchester Station are a pure strain, and the purpose of the study was to determine whether or not this strain might be less migratory than the rainbow trout generally being used in eastern United States for stocking purposes.

The study was conducted by comparing the migratory tendencies of the Manchester (Iowa) strain with rainbow trout developed from eggs obtained from the U. S. Fish and Wildlife Service stations at Wytheville, Virginia, and Walhalla, South Carolina. No attempt has been made to maintain the stock as a pure strain at these latter stations, and it was believed that they might fairly represent the average trout used for restocking in the eastern States. By marking equal numbers of both groups of fish, and by stocking proportionately, a comparison of the actual migrations was possible. The studies were made on the streams of the Cooperative Wildlife Management Areas in western North Carolina, where all fishermen are required to obtain a permit upon entering and to have their creels checked upon leaving the areas.

METHODS

Three streams in three different management areas were selected as test sites. A 10-mile section of each stream was designated as a test area. Beginning at the downstream end of each, numbered signs were posted along the stream banks at 0.25-mile intervals. The signs, numbered from 1 to 40 on each area, were so posted as to be visible from either upstream or downstream. The distance between the signs was measured with a pedometer. The streams selected are considered better than average rainbow trout streams, and annually they support a moderately heavy fishing pressure.

The test fish were tagged with monel metal strap-type fish tags, size No. 1, as supplied by the National Band and Tag Company, Newport, Kentucky. Serially numbered tags were used in order that each individual fish might be identified. Each fish was tagged on the operculum. After tagging, all test fish were held in hatchery pools at least 24 hours to make sure there was no immediate tagging loss. The fish were stocked during the latter half of March 1952, in preparation for the opening of the fishing season on April 15. Consequently, a minimum period of 2 weeks was permitted for migratory tendencies to become evident.

Creel checkers at the entrance stations on the three test areas were instructed to inform the fishermen of the studies being conducted and to request their cooperation. In addition, each fisherman was given a prepared statement of the aim of the study to emphasize its importance. The statement is reproduced here.

MR. FISHERMAN:

YOUR COOPERATION IS REQUESTED IN FINDING OUT MORE ABOUT THE MIGRATORY HABITS OF TROUT. TAGGED TROUT HAVE BEEN STOCKED IN THIS AREA. EACH TAG CARRIES A NUMBER. POINTS ALONG THE MAIN STREAM ARE POSTED WITH NUMBERED SIGNS. WHEN YOU CATCH A TAGGED TROUT, PLEASE WRITE THE TAG NUMBER AND THE NEAREST SIGN NUMBER IN THE PROPER PLACE ON THE BACK OF THE PERMIT ISSUED TO YOU. SHOULD YOU CATCH A TAGGED TROUT IN A TRIBUTARY OF THE MAIN STREAM, PLEASE INDICATE THE NUMBER OF THE TAG, AND THE TRIBUTARY AND THE APPROXIMATE DISTANCE FROM THE MAIN STREAM.

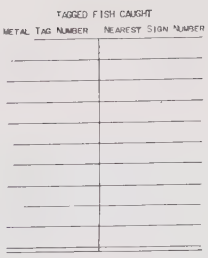
MANY THANKS,

NORTH CAROLINA WILDLIFE RESOURCES COMMISSION.

Upon entering a management area, a fisherman leaves his fishing license at the checking

Presented at the Sixth Annual Conference of the Southeastern Association of Game and Fish Commissioners in Savannah, Georgia, October 19-22, 1952.

station in order to insure his return through that station. He is supplied with a permit for the area. Upon this permit the checker records the angler's catch at the time of his departure. In this study, all permits were stamped on the reverse side so that the fishermen could show the tag number and the nearest sign number of each test fish caught. The stamp used is reproduced above.



On Fires Creek and on Big Santeetlah Creek, the test fish were stocked in four equal parts at various places in the test area. On Nantahala River, the test fish were all stocked at one location. The purpose in the two types of stocking was to obtain some indication of whether or not rainbow trout might be expected to disperse through a stretch of water from one stocking point, or whether the customary procedure of numerous smaller stockings is necessary to insure an adequate distribution of fish throughout the length of the stream.

On all three test streams, additional untagged trout were stocked above and below the stocking points of test fish in order that there would be no forced migration which might result from unbalanced pressures on the existing food supply.

AREA NO. 1. FIRES CREEK

Only rainbow trout are found in Fires Creek. There are no barriers to migration in the main stream, and only one tributary is accessible to fish in the test area. The creek is clear, turbulent, and contains many excellent pools. Numbered signs were located along the creek, beginning at the downstream boundary of the management area and continuing upstream for 10 miles. One hundred of each of the two strains of tagged trout were stocked at each of four separate locations. Starting from the downstream boundary, the first stocking was made just above the 1-mile point, the second stocking at 4 miles, the third stocking at 6.25 miles, and the fourth at 7.25 miles. The exact stocking points were

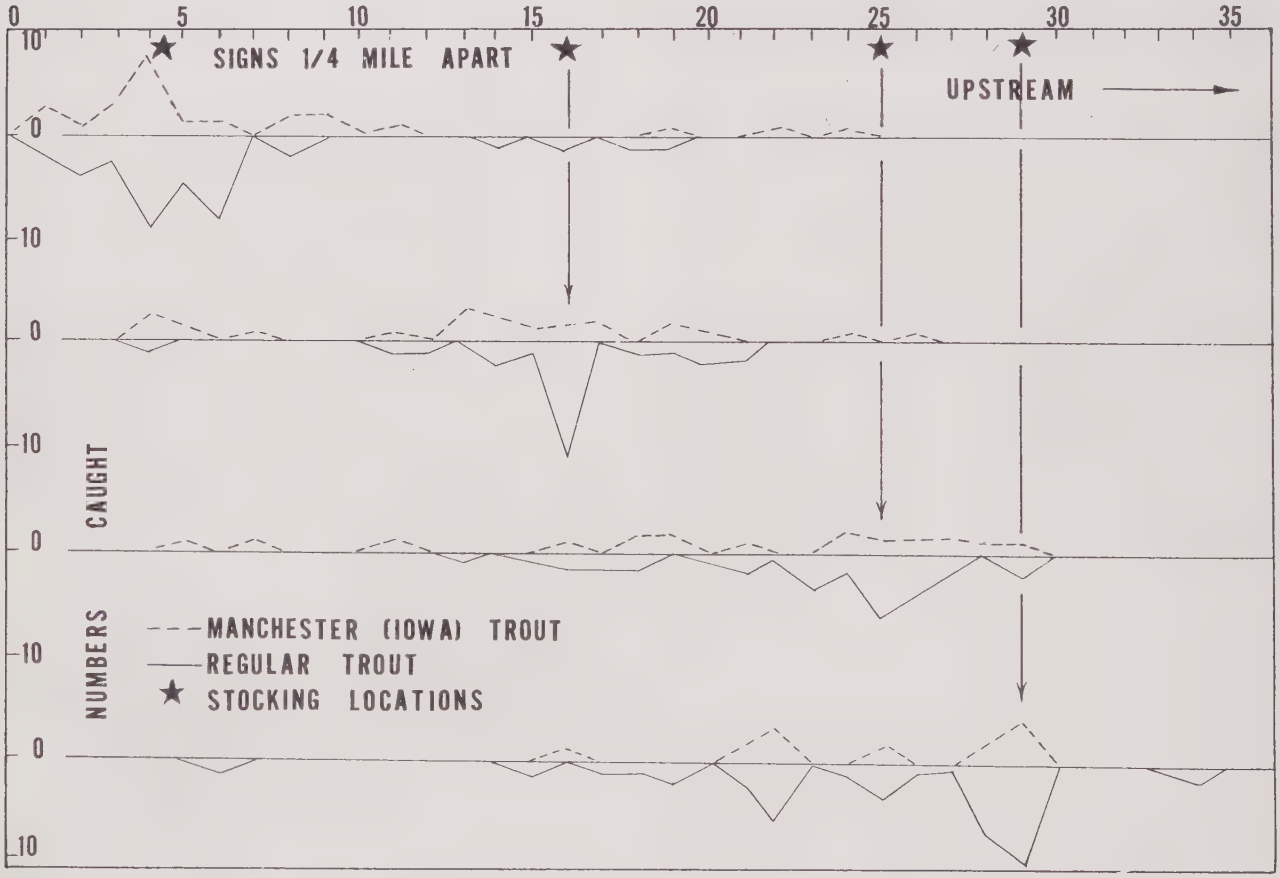


FIGURE 1.--Stocking points and recovery points on Fires Creek.

TABLE 1.--Fires Creek

Tagged fish stocked Stocking locations and numbers stocked	Sign Nos. ¼ mile	Tagged fish recovered--by stocking points Sign No. 4½ Man.	Reg.	Sign No. 16 Man.	Reg.	Sign No. 25 Man.	Reg.	Sign No. 29 Man.	Reg.	Total
	1	3	2	-	-	-	-	-	-	5
	2	1	5	-	-	-	-	-	-	6
	3	3	3	-	-	-	-	-	-	6
100 Manchester and 100 Regular	4	7	9	3	1	-	-	-	-	20
	5	2	5	1	-	1	-	-	-	9
	6	2	8	-	-	-	-	-	1	11
	7	1	-	1	-	1	-	-	-	3
	8	2	2	-	-	-	-	-	-	4
	9	2	-	-	-	-	-	-	-	2
	10	-	-	-	-	-	-	-	-	-
	11	1	-	1	1	1	-	-	-	4
	12	-	-	-	1	-	-	-	-	1
	13	-	-	4	-	-	1	-	-	5
	14	-	1	3	3	-	-	-	-	7
	15	-	-	1	1	-	1	-	1	4
100 Manchester and 100 Regular	16	-	1	2	11	1	2	1	-	18
	17	-	-	2	-	-	2	-	1	5
	18	-	1	-	1	2	2	-	1	7
	19	1	1	2	1	2	-	-	2	9
	20	-	-	1	2	-	1	-	-	4
	21	-	-	-	2	1	3	2	2	10
	22	1	-	-	-	-	1	4	5	11
	23	-	-	-	-	-	4	-	-	4
	24	1	-	1	-	3	3	-	1	9
100 Manchester and 100 Regular	25	-	-	-	-	2	6	2	4	14
	26	-	-	1	-	2	4	-	1	8
	27	-	-	-	-	2	2	-	-	4
	28	-	-	-	-	1	-	2	8	11
100 Manchester and 100 Regular	29	-	-	-	-	1	2	4	10	17
	30	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	-	-	-	-	-
	32	-	-	-	-	-	-	-	-	-
	33	-	-	-	-	-	-	-	-	-
	34	-	-	-	-	-	-	-	2	2
	35	-	-	-	-	-	-	-	-	-
	36	-	-	-	-	-	-	-	-	-
	37	-	-	-	-	-	-	-	-	-
	38	-	-	-	-	-	-	-	-	-
	39	-	-	-	-	-	-	-	-	-
	40	-	-	-	-	-	-	-	-	-
Manchester totals 400		27		23		20		15		85
Regular totals 400			38		24		34		39	135
Totals 800		65		47		54		54		220

determined, to some extent, by accessibility for the hatchery truck.

Figure 1 indicates the stocking locations and the recovery points for each of the test fish caught in Fires Creek. It will be observed that there was little difference in the upstream and downstream migration from the downstream stocking point. From the 4-mile stocking point, both upstream and downstream migrations were relatively balanced, although the downstream tendency was slightly greater. From the sixth- and seventh-mile stocking points, a very definite downstream migration tendency existed. A reasonable explanation for the difference in migration from the various stocking points might well be that the stream is sufficiently smaller in its upper reaches to encourage downstream migration. It is to be observed that no significant difference between the test fish of either of the two groups is exhibited.

During the 1952 trout fishing season, extending from April 15 to the end of August, the Fires Creek Management Area was stocked with 2,800 rainbow trout, and 3,981 trout were caught. The stream was fished for a total of 914 man-days. The average catch was 4.4 fish; the catch rate was 1.2 fish per man-hour.

Of the 800 tagged trout stocked in the area, 220 were recovered. Of these, 85 were of the Manchester (Iowa) strain and 135 were of the regular hatchery strain. Table 1 shows the migration of the individual fish from the stocking points to the recovery points.

AREA NO. 2. BIG SANTEETLAH CREEK

The same general procedure used for stocking trout on Fires Creek was followed on Big Santeetlah Creek. The signs at 0.25-mile intervals were begun at the downstream area boundary and continued upstream for 10 miles. A suspected barrier to trout migration, in the form of a fall, is located 6.75 miles above the downstream boundary on the main stream. There are several small tributaries in the test area. The dominant species of the whole area is rainbow trout, but small populations of brook and brown trout are present.

Again, in this area, 800 tagged fish were stocked. One hundred of each strain were stocked at each of four locations. The first stocking was at sign 11, 2.75 miles above the downstream boundary; the second stocking was at 3.75 miles; the third at 5.25 miles; and the fourth at 6.25 miles, just below the barrier. Again, additional trout were stocked in the stream to equalize the pressure on the food supply.

There was little migration in either direction by either group of test fish from the downstream stocking. There was a general migration both upstream and downstream from the second stocking station. Tagged fish moved both upstream and downstream from the third station but generally moved downstream from the fourth. It is significant that only one fish was reported as having moved upstream past the fall. This report may have been correct, or it may have been erroneous. Figure 2 shows the stocking points and the recovery points of the tagged fish in this area.

Prior to and during the 1952 fishing season, the test area was stocked with 2,250 rainbow trout, 900 brook trout, and 925 brown trout, or a total of 4,075 fish. The catch consisted of 3,902 rainbow trout, 1,367 brook trout, and 408 brown trout, or a total of 5,677 fish. Fishing pressure on the area consisted of 1,180 man-days, taking an average catch of 4.8 fish at the rate of 1.2 fish per man-hour.

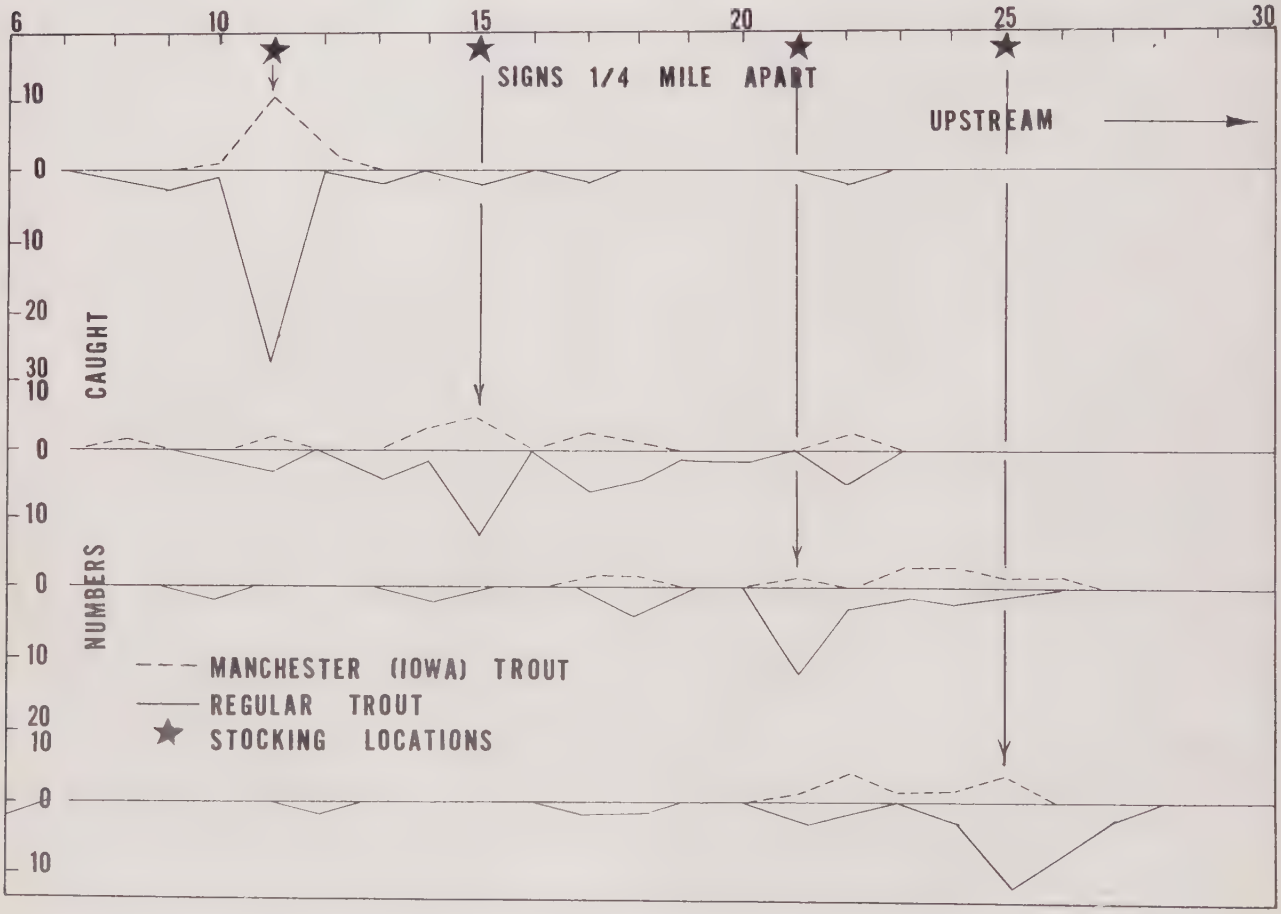


FIGURE 2.--Stocking points and recovery points on Big Santeetlah Creek.

TABLE 2.--Big Santeetlah Creek

Tagged fish stocked Stocking locations and numbers stocked	Sign Nos. ¼ mile	Tagged fish recovered--by stocking points Sign No. 11		Sign No. 15		Sign No. 21		Sign No. 25		Total
		Man.	Reg.	Man.	Reg.	Man.	Reg.	Man.	Reg.	
	1	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	5	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	1	1
	7	-	-	-	-	-	-	-	-	-
	8	-	1	1	-	-	-	-	-	2
	9	-	2	-	-	-	-	-	-	2
	10	1	1	-	1	-	1	-	-	4
100 Regular and 100 Manchester	11	10	28	1	2	-	-	-	-	41
	12	2	-	-	-	-	-	-	1	3
	13	-	1	-	4	-	-	-	-	5
	14	-	-	2	1	-	2	-	-	5
100 Regular and 100 Manchester	15	-	1	3	13	-	1	-	-	18
	16	-	-	-	-	-	-	-	-	-
	17	-	1	2	6	1	-	-	1	11
	18	-	-	1	5	1	3	-	1	11
	19	-	-	-	1	-	-	-	-	1
	20	-	-	-	1	-	-	-	-	1
100 Regular and 100 Manchester	21	-	-	-	-	1	12	1	3	17
	22	-	1	2	3	-	3	3	1	13
	23	-	-	-	-	2	1	1	-	4
	24	-	-	-	-	2	2	1	2	7
100 Regular and 100 Manchester	25	-	-	-	-	1	1	3	11	16
	26	-	-	-	1	1	-	-	6	8
(Barrier)	27	-	-	-	-	-	-	-	1	1
	28	-	1	-	-	-	-	-	-	1
	29	-	-	-	-	-	-	-	-	-
	30	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	-	-	-	-	-
	32	-	-	-	-	-	-	-	-	-
	33	-	-	-	-	-	-	-	-	-
	34	-	-	-	-	-	-	-	-	-
	35	-	-	-	-	-	-	-	-	-
	36	-	-	-	-	-	-	-	-	-
	37	-	-	-	-	-	-	-	-	-
	38	-	-	-	-	-	-	-	-	-
	39	-	-	-	-	-	-	-	-	-
	40	-	-	-	-	-	-	-	-	-
Manchester totals 400		13		12		9		9		43
Regular totals 400			37		38		26		28	129
Totals 800		50		50		35		37		172

Of the 800 tagged fish stocked, fishermen recovered 172. These included 43 fish of the Manchester (Iowa) strain and 129 of the regular hatchery trout. Table 2 shows the stocking points and the recovery points of the tagged fish from this test area.

AREA NO. 3. NANTAHALA RIVER

Nantahala River, in Standing Indian Management Area, is predominantly a rainbow trout stream although there are a few brook trout in the upper reaches and a few brown in the lower section. There are numerous small tributaries to the main stream; a 5-foot fall is 1 mile above the downstream boundary of the area. As on the other areas, numbered signs were placed along the main stream, beginning at the downstream boundary and extending upstream for 10 miles.

This area was stocked with a total of 600 tagged trout, which consisted of 300 of each of the two strains being studied. All the tagged fish were stocked at sign 16, 4 miles above the lower boundary of the area. Additional unmarked trout were stocked to equalize the pressure on the food supply. Figure 3 indicates the stocking location and the extent of migration. It will be observed that the general migration trend was downstream, although the major recovery was in the vicinity of the stocking point. Migration tendencies of the two strains showed no significant difference.

Before and during the 1952 trout fishing season, the Nantahala River was stocked with 2,800 rainbow trout and 950 brown trout, or a total of 3,750 fish. The catch on this area consisted of 4,490 rainbow trout, 617 brown trout, and 157 brook trout, or a total of 5,264 fish. This catch was made in 1,143 man-days of fishing, for an average catch of 4.6 fish, at the rate of 1.0 fish per man-hour.

Of the 600 tagged fish stocked, 245 were recovered. The recovery consisted of 111 trout of the Manchester (Iowa) strain and 134 of the regular hatchery strain. Table 3 shows the migration of individual fish from the original stocking point to the points of recovery.

OBSERVATIONS AND CONCLUSIONS

Considerable difficulty was experienced in the transportation and propagation of the Manchester (Iowa) trout. An allotment of 10,000 eggs was shipped from the Manchester Station to the Leetown (West Virginia) Station of the U. S. Fish and Wildlife Service. At the Leetown Station the eggs were hatched and the fish were reared to a size of approximately 2.5 inches. At this size, 8,000 remained. Fish-distribution units of the North Carolina Wildlife Resources Commission picked up the 8,000 trout and transported them to the Arrowood Glade Rearing Station near Franklin, North Carolina. Approximately 7,000 arrived alive.

During all of their subsequent rearing period, these fish demonstrated an unusual state of shock. It was necessary to cover the rearing pools to prevent losses occasioned by their wild gyrations when visitors approached. For a long period the pools could not be cleaned because of the resulting shock losses. Only 1,100 remained when the fish were stocked at a size of 7 inches. Throughout this study, the recovery of Manchester (Iowa) trout was consistently smaller than the recovery from the controls. From the history of the rearing of these fish, it seems reasonable to assume that a higher mortality rate may have continued to exist

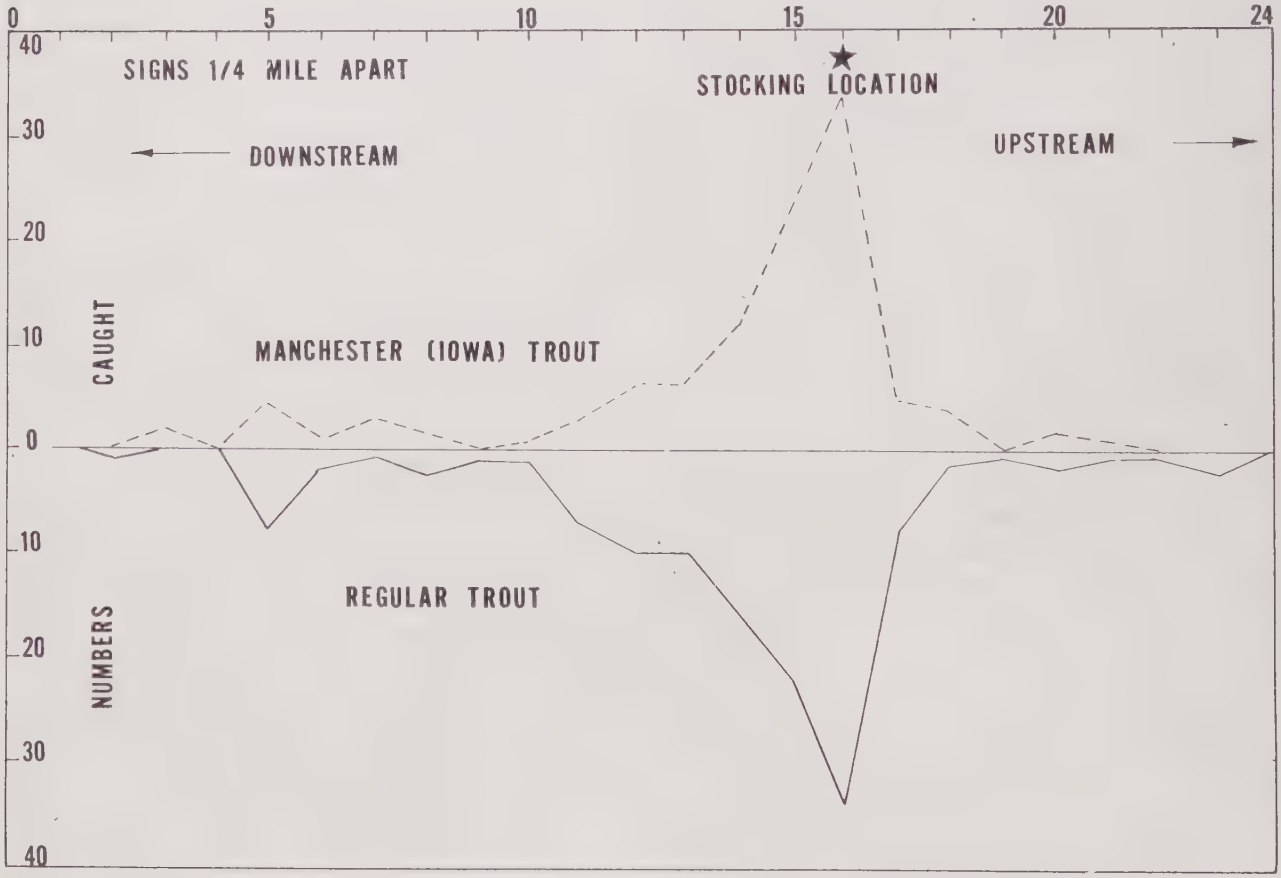


FIGURE 3.--Stocking point and recovery points on Nantahala River.

after the fish were introduced into the streams, possibly as a result of handling during stocking.

Without a doubt, the recovery of tagged fish was greater than the totals indicated on the data sheets. Occasional illegible records provided by the fishermen were discarded. Also, it is known from the torn gill flaps that numerous tagged fish lost their tags prior to capture. The incidence of fish with torn gill flaps but without tags increased during the season, and no fish bearing tags were taken during July or August.

This had some effect on the total recovery percentages; but from the existing records, it is unlikely that it resulted in any disparity between the percentage recoveries of the two strains. Also, since the heaviest fishing pressure occurred during the first month of the season, it is likely that this loss of information on recovered fish was not so great as might first be assumed.

Although daily temperature records were not kept on the streams of the test areas, water temperatures at the beginning of the fishing season, subsequent to stocking, averaged 43°. From the occasional records available, it is believed that stream temperatures reached 50° about May 30 and were approximately 66° when the fishing season closed at the end of August.

From consideration of the graphs of the three areas, it can be concluded that there was a slight general tendency for the test fish to move downstream. In the larger waters near the lower end of the test sections, little directional migration was indicated. Most downstream migration resulted from stockings in the upper and smaller parts of the test area streams.

From the "one spot" stocking made on the Nantahala River, it can be concluded that the dispersal of fish from such a stocking is not comparable to the results obtained by using several stocking locations. Within the few weeks available for migration, the fish failed to distribute themselves in desirable numbers throughout available waters of the test area.

Finally, it can be concluded that there is no significant difference in the migratory tendency of the Manchester (Iowa) strain of rainbow trout as compared with the rainbow trout being used as controls.

TABLE 3.--Nantahala River

Tagged fish stocked Stocking locations and numbers stocked	Sign Nos. ¼ mile	Tagged fish recovered--by stocking points Sign No. 16		Total
		Man.	Reg.	
	1	-	-	-
	2	-	1	1
	3	2	-	2
(Barrier)	4	-	-	-
	5	4	7	11
	6	1	2	3
	7	3	1	4
	8	2	3	5
	9	-	2	2
	10	1	2	3
	11	3	7	10
	12	6	10	16
	13	6	10	16
	14	13	17	30
	15	23	24	47
300 Regular and 300 Manchester	16	34	32	66
	17	5	7	12
	18	4	2	6
	19	-	1	1
	20	2	2	4
	21	1	1	2
	22	-	1	1
	23	-	2	2
	24	-	-	-
	25	-	-	-
	26	-	-	-
	27	-	-	-
	28	-	-	-
	29	-	-	-
	30	-	-	-
	31	-	-	-
	32	-	-	-
	33	-	-	-
	34	-	-	-
	35	1	-	1
	36	-	-	-
	37	-	-	-
	38	-	-	-
	39	-	-	-
	40	-	-	-
Manchester totals 300		111		111
Regular totals 300			134	134
Totals 600				245

"If, as science asserts, a fish diet is a fortifier of the brain, who needs it more than the restless, rushing, irrepressible American?"--U. S. Commissioner of Agriculture, 1868.

THE APPLICATION OF LAND USE TO FISHERIES MANAGEMENT IN MICHIGAN

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IN THE EARLY SPRING OF 1950, the Michigan Department of Conservation gave the green light to a pilot or experimental project involving the development of a watershed on a comprehensive land-use basis. This approval was the end result of a long period of discussion and study involving fish habitat and management work. It was believed by the majority of the staff of the Fish Division that a general land-use program taking into consideration agriculture, forestry, game, and fish--in fact, all aspects of a conservation program, using the word conservation in its broadest sense--could be justified from a fisheries angle alone. The resulting improved soil and water conditions would be reflected in the greater production of desirable fish. This really represented a considerable jump forward in thinking. It was necessary to overcome prejudices, the habit of thinking along lines of limited objectives, and the idea that, to benefit fish, work must be confined to water alone. Perhaps the most difficult hurdle of all was the very breadth and size of such an undertaking.

Work was started on July 1, 1950, using fish license money. Prior to this, a meeting had been called of all agencies that might have an interest in such a development. Included were the U. S. Soil Conservation Service, the U. S. Fish and Wildlife Service, the U. S. Forest Service, the U. S. Geological Survey, the U. S. Weather Bureau, the various divisions of the Michigan State Conservation Department, Michigan State College, and the University of Michigan. The direct result of this meeting was an operational plan whereby it was recommended that contact should be made with the county organizational units and the local village organizations. As the area selected was the Rifle River watershed in Ogemaw County, where no soil conservation district had yet been organized, it was necessary that the Fish Division employ a farm planner. Shortly after the program was under way, the county did organize and the soil service and the Fish Division farm planners cooperated, their plans being interchangeable and acceptable to each group.

A great deal of time and effort went into the development of operational plans, but the purpose of this article is to relate the accomplishments in the two and one-half years that the watershed program on the Rifle River has been functioning.

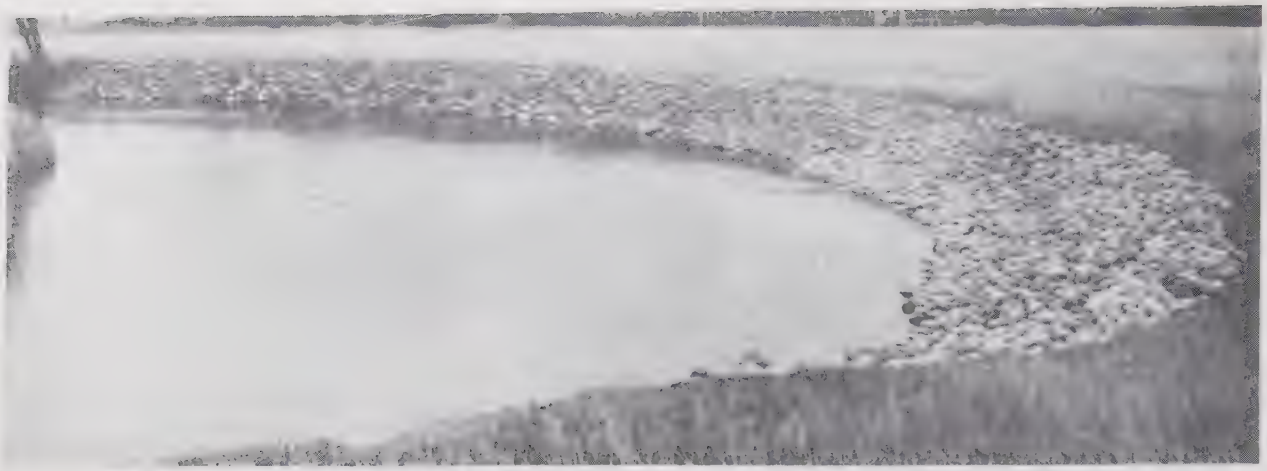
It was deemed essential at the start to provide a proper inventory and the necessary maps of the hundred thousand acres comprising the watershed. The area was flown and photographed, and from these pictures a drainage map was made. These aerial photos also provided the base for cover maps and, together with the soil surveys, for capability and ownership maps. From this material the problems of the area have been crystallized into a number of units:

1. Ownership. This was subdivided into public and private ownership. The private ownership was divided into agricultural and nonagricultural land.
2. Erosional losses and the resulting siltation problems in the streams.
3. The types of agriculture practiced in the area and their effects on soil loss and ground water.
4. The degree of bank erosion on the streams, their sedimentation, suspended silt and bed loads, flood potential, and base flow.

(OPPOSITE PAGE)

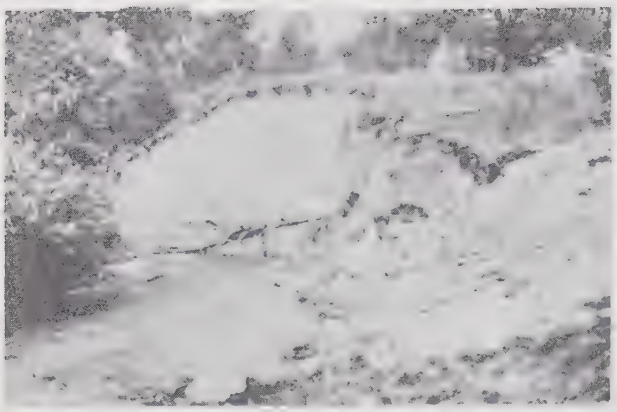
TOP: . Stabilization of an eroding bank by reduction of slope, sodding, and riprap.
BOTTOM: Same stream section after completion, with fence to limit stock access.

(All photographs courtesy the author.)



TOP: Control by riprap of an eroding bend in stream.
CENTER: Stream section in process of improvement.
BOTTOM: Same stream section after completion of improvement measures.

TOP: Headwater retention reservoir.
BOTTOM: Tree planting in cooperation with land owner to restrict run-off waters.



Bank before work.

Same bank after stabilization.

Bank controls.

(THE NEXT THREE PHOTOGRAPHS)

The two photographs on the next page and the photograph on the following page show the effects of 11 years of stream improvement work. These photographs were taken in 1941, 1946, and 1952, respectively. Note the narrowing of the channel.

1941

1946

Third view (1952) of the same stream shown in the two preceding photographs.

It became apparent at the start that the problem was going to be confined largely to the agricultural land under private ownership and to the destructive methods employed to provide highway drainage on the secondary roads. At this initial stage there was begun a system of data collecting which will indicate the efficacy of many techniques employed. A brief listing of these may be of interest:

1. Meteorological data; automatic recording rain gauges on a grid basis over the area. These were supplemented by many manually operated gauges. A complete weather station was installed in cooperation with the U. S. Weather Bureau.

2. Four recording stream-flow gauges with automatic recording thermographs to measure water temperatures were installed at strategic points along the stream system. These were installed and operated on a cooperative basis with the U. S. Geological Survey. In addition, a gauge station located a short distance from the mouth of the Rifle River has been in operation for a number of years.

3. In cooperation with the U. S. Soil Conservation Service, estimates of soil loss were made on the basis of soil characteristics, precipitation records, topography, and land use.

4. Fish population studies and estimates were made by staff members of the Institute for Fisheries Research (the research organization of the Fish Division of the Michigan Department of Conservation.

5. In cooperation with the U. S. Geological Survey, seepage runs were made as nearly simultaneously as possible on all the major tributaries of the Rifle River above Selkirk, Michigan.

The collection of all these data will continue. It is hoped that an evaluation of the project may be made from them.

The construction work on the Rifle River was largely completed at the end of 1952. This was approximately 2 years ahead of schedule and at a fourth less than the original estimated cost (which was $200,000, to be spread over a 4-year program). Measures to conserve soil and water, as well as a farm cooperative program, are a continuing part of a watershed program and are essential if the full benefits are to be realized.

To a great extent, the cooperative effort with the private land owners and the various agencies has assured the success of the program. Seventy-five percent of the farmers are cooperators, and the percentage is continually increasing. These farmers are furnished the approved type of farm plan mutually acceptable

A raw, vertical eroding bank dressed back and under complete control.

to the Conservation Department, the U. S. Soil Conservation Service, and the individual farmer. These plans are based on the soil capabilities as outlined in the Soil Conservation Service farm plans, which involve agricultural recommendations, stream bank control, grassed waterways, infiltration and flood-control reservoirs, current deflectors, tree plantations, and the limiting of stock access to the streams. The work that is largely of benefit to the individual property owner under the farm plan was done by him, and the work that is of major benefit to the watershed was done by the Department of Conservation. The determination of this benefit rested entirely with the Department. Prior to the initiation of the watershed program, a policy was adopted requiring only the permission of the land owner for the Department to construct and maintain essential devices on private land. This arrangement has worked admirably.

Accomplishments to date are itemized as follows:

A diversion channel (½ mile long) was constructed in Gamble Creek, bypassing Devoe Lake. At the diversion head a two-way control weir was built to permit the cold base flow of the stream to enter directly into the Rifle River. This reduces the temperature of the Rifle River during the critical hot months. The other portion of the weir permits the flood water to pass directly into Devoe Lake, stabilizing the flow of the upper Rifle. Construction effort on the watershed included the following items: (1) 8 miles of grass waterways; (2) 191,000 trees planted on critical eroding areas; (3) 7,110 feet of fence for protection of new tree plantations. The construction work completed on the stream phase of the project is as follows: (1) 113 eroding banks stabilized with rock riprap, jetties, grading, sodding, etc.; (2) 9 miles of stream improved by the addition of 106 structures for formation of pools, cover, spawning, and food purposes; (3) 24,900 feet of streamside fence to protect stream banks and vegetation; (4) 400,000 trees planted along streams for shade, trout cover, and bank stabilization purposes.

Tremendous interest has been shown in this project by people of the State of Michigan, other States, and foreign countries. This is evidenced by the fact that during the 2 years approximately 4,000 individuals have visited the area. This number represents only those belonging to organized groups making conducted tours. Many requests--throughout the State and at the Department's Training School at Higgins Lake--for formal meetings to discuss the watershed approach were made and fulfilled.

VIRUS DISEASES IN FISHES:
OUTLOOK FOR THEIR TREATMENT AND PREVENTION

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VIRUSES ARE PATHOGENIC AGENTS which can pass through bacterial filters and which can be cultivated only in substrates containing living--preferably growing or multiplying--cells. The true nature of at least some groups of viruses is still being disputed (Beard 1951).

Viruses attack people and all higher vertebrates. Viruses are found in various lower vertebrates and are particularly widely represented among arthropods. Insects serve as vectors or intermediate hosts of many virus diseases of animals and plants. Practically all domestic and many wild plants are subject to virus diseases.

Bacteriophages are viruses which are specifically pathogenic to various species of bacteria. True viruses cannot be seen with the aid of an ordinary light microscope; they have been seen for the first time with the advent of the electron microscope, which now is the most useful tool in the study of viruses. There are other obligate parasites, large enough to be seen with the aid of the ordinary light microscope, which also can be cultivated only in living organisms or in media containing living tissues or extracts from chick embryos. These microorganisms belong to the order Rickettsiales. Microorganisms belonging to this order may be considered intermediates between bacteria and the true viruses (Bedson et al. 1950).

It is a general rule, with some exceptions, that immunity caused by infection with a virus (smallpox or yellow fever, for example) is of much longer duration than immunity resulting from a bacterial infection (typhoid). This is explained by various theories. One theory which seems plausible to me is that viruses, being intracellular parasites, persist in cells after the recovery of the host from the infection and thereby stimulate a steady production of specific antibodies. It is impossible to immunize animals with dead virus.

Bacterial diseases can be controlled by sanitary measures, therapy, and immunization. Therapy of the true virus diseases is practically nonexistent at this time. Diseases caused by microorganisms belonging to the order Rickettsiales--diseases such as typhus, parrot fever, and possibly kidney disease of salmonid fishes (Rucker et al., in press)--respond well to treatment with some of the antibiotics (aureomycin, chloramphenicol, etc.) and drugs like para-aminobenzoic acid (Eaton 1950). Sulfa drugs and antibiotics work because of the differences in the metabolic activities of cells of hosts, bacteria, and some rickettsias. If such differences did not exist, it would not be possible to inflict injury on the parasite without harming the host. Kopper reported (1952):

> "The less independent an organism is in its metabolic activities, the fewer are the vital links that may be broken or blocked through chemical agents without causing injury to the host. It is for this reason that chemotherapeutic treatment in virus infections has generally met with disappointing results."

As things stand now, it is unlikely that general chemotherapeutic measures, directed against true virus diseases, will be developed soon. Unlike bacteria, viruses are intracellular parasites; therefore, it would be necessary to find antimetabolites such as sulfonamides, antibiotics, etc., which would penetrate the cells of the host and attack virus particles specifically without affecting the host cells. As the nutrition of true viruses is undoubtedly linked closely with that of the host cells, it will be difficult to find specific virus antimetabolites. Discovery of such an agent is possible but not very likely in the near future.

Apparently only two practical approaches are available at this time for the control of virus diseases in fishes and other animals.

The approach immediately available is the use of sanitation; the long-range approach is the breeding of resistant strains of fish. Because viruses may be transmitted in fish eggs, in adult fish which are living or dead, or in any aquatic animals (other species of fish, copepods, insects, leeches, etc.), studies should be made with the objective of locating the source of infection and eliminating it. This is not a simple problem. Work on the mode of transmission of the polio virus may serve to illustrate how complicated, expensive, and frustrating such work can be. Therefore, the control of fish virus diseases by sanitary measures may be considered the only method currently available.

Recently some German scientists reported that "carp dropsy" is basically a virus disease and that the agent is transmitted, among other ways, inside apparently normal carp eggs. The presence of the virus in the infected carp eggs was discovered through the use of an electron microscope. Virus investigations in American fish disease laboratories would be greatly facilitated with electron microscopes.

The immediate control of virus diseases of fishes (Nigrelli 1952) in inland waters and in hatcheries should be approached through the application of both sanitary measures and breeding practices. For a proper and rational application of sanitary measures, it will be necessary to make a thorough study of the nature of the different virus fish diseases and their mode of transmission. The progress in this field will be very slow, owing to the fact that there is but one fish pathologist for at least several thousand human, veterinary, and plant pathologists. Also, the amount of money available for the study of fish diseases is very small as compared with the hundreds of millions of dollars spent annually on the study and prevention of human, animal, and plant diseases.

I have observed that the incidence of numerous hitherto-unreported diseases of brook trout is increasing in eastern United States. This may be due in part to incidental breeding of brook trout strains that have a low resistance. Consequently, it would be very desirable to make a thorough study of the hereditary resistance and susceptibility of trout strains to various infectious diseases. This is a long-range project, but it is much needed and holds promise of good results. Research in this field is being started at the Rome hatchery in the State of New York (Wolf 1951). Obviously, such an approach is not possible for the salmon, which spends much of its life in the ocean.

Another way in which work on diagnosis and treatment of fish diseases could be speeded up would be by the organization of a field diagnostic service to be a liaison between the research laboratories and the field. Research, if of high quality, is a full-time job, and frequent interruptions of experimental work render progress very slow. The agricultural research in this country is excellently organized: research is conducted in the central laboratory at Beltsville, Maryland, and in a number of regional laboratories. The Agricultural Extension Service constitutes the link between these laboratories and the farmers.

The recommendations which I should like to outline for the control of virus diseases in the salmon hatcheries of the West Coast, as well as for other hatcheries, are as follows:

1. Continue to make thorough studies of the nature, the mode of transmission, and the eventual therapy of virus diseases of fishes. This is a long-range project of the utmost importance. There are indications that one of the promising approaches to the control of virus diseases may be through nutrition (Kopper 1952), and this avenue should be given careful attention.

2. Eliminate all fish from the affected hatchery, disinfect the hatchery, and kill all the animals in the water supply system. If such a course is practicable, the disease should be permitted to run its course and the surviving fish should be used for breeding.

3. Start with good eggs; disinfect them to eliminate any pathogens which may be on the surface of the eggs. Eliminate all dead eggs.

4. Until the animal vector of the disease is discovered, keep the water supply to the hatchery constantly free from animals of any kind.

5. If another outbreak occurs, immediately destroy and disinfect all infected fish except those needed for research, and isolate the healthy fish. With a rational approach and a real determination, this can be accomplished fairly easily.

6. If a disease breaks out among salmon which were fed eggs or viscera of adult salmon or any other unsterilized fish material, the practice of feeding such food should be discontinued until it can be proved that the food is harmless. If a disease breaks out more or less simultaneously among salmon in several well-separated hatcheries, it is reasonable to suspect that infection was transmitted through eggs or other fish products. I am very definitely opposed to feeding fry

or fingerlings with raw eggs, unsterile salmon viscera or whole fish. Adult salmon and probably other fishes must be considered the likely carrier of fish diseases; hence any possible contact between the adult and the young fish should be avoided at all cost. All sanitary measures, therapy, and disinfection may be considered a waste of effort and money if small fish are fed with food which was part of, or in contact with, adult fish which were not known to be free of any contagious disease.

Viruses cause a vast number of infectious diseases in animals and plants. Therefore, it is only logical to assume that a number of important virus diseases of fishes will be "discovered" when the research on these diseases is given at least some of the stimulus and attention which such research fully deserves.

Drs. P. J. Griffin and E. M. Wood have read this report and made suggestions.

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USE OF THREE ANESTHETICS ON JUVENILE SALMON AND TROUT

During the work of measuring and weighing salmon and trout at Bare Lake, Kodiak Island, Alaska, as part of the studies of the Pacific Salmon Investigations of the U. S. Fish and Wildlife Service, P. R. Nelson tried various concentrations of tricane methanesulfonate, urethane, and chlorobutanol as anesthetics for coho salmon, red salmon, and Dolly Varden trout.

Under the conditions prevailing at Bare Lake, the concentrations listed below were most desirable for anesthetizing red salmon juveniles and the fry of coho salmon and Dolly Varden trout. To obtain the most satisfactory results in anesthetizing coho salmon fingerlings and Dolly Varden trout fingerlings, slightly higher concentrations of these chemicals were required.

Anesthetic	Date used	Water temp. °C.	Most desirable concentration
Tricane methanesulfonate	7/51	13-17	1:12,500
Urethane	6/51-8/51	10-18	1:190
Chlorobutanol	7/51	16	1:2,000

Mr. Nelson reported that each of these chemicals, when applied in the concentrations listed, required several minutes to anesthetize the fish. Occasionally a fish that apparently was anesthetized flipped while it was in the weighing pan, but occurrences of this nature seemed inevitable if mortality of the fish was to be held to the minimum. No ill effects were noted when fish were permitted to remain in these solutions for a short time after being anesthetized.

Very low mortality resulted from the use of any of these three chemicals in the concentrations listed here. When, however, anesthesia with tricane methanesulfonate in a concentration of 1:10,000 was undertaken, 100 percent mortality was noted. Similarly, experiments with urethane and chlorobutanol showed that there was only a rather small latitude of concentrations whereby mortality of the fish could be restricted to very low figures.

CHANGES IN THE COMMERCIAL FISHERY ON THE ALABAMA PORTION OF THE TENNESSEE RIVER

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THE TENNESSEE RIVER of north Alabama was fished by a small number of commercial fishermen before it was changed into a series of reservoirs. Most of these men were only part-time fishermen who spent the rest of their time at such other occupations as farming and trapping. They fished for buffalo and drum during the latter part of the winter and early spring, for catfish at other seasons. Many people along the river had their own lines and caught fish for their own use, thus making it difficult for commercial fishermen to dispose of large catches. Buffalo and drum were taken mostly in nets; catfish were taken on baited lines.

A commercial fish census in 1935-36 on the part of the Tennessee River that was to become Wheeler Reservoir indicated an annual catch of 57,000 pounds of buffalo, drum, and catfish.

Wheeler Dam was completed in the fall of 1936. That same year the Alabama Legislature passed the Sanford Act, prohibiting all netting in impounded waters. Normal fishing practices were thus disrupted both by impoundment and by legislation.

Early Post-Impoundment Fishing, 1936-45

From 1936 to 1941 legal commercial fishing was done with baited lines. The commercial catch declined during this period. Major species were catfishes and bullheads. At the same time, rough fish increased rapidly in number. Carp, buffalo, and drum were abundant in fish population studies, but very few of them showed up in the catch. Soon after impoundment of Wheeler, Guntersville, and Pickwick Reservoirs, it became evident that some additional harvesting and control of food and rough fish would be needed to assure good sport fishing.

By 1941 opportunities in industry had improved. Wages offered by defense plants were a lot more attractive than income from fishing. The result was fewer commercial fishermen at a time when meat was scarce and a greater harvest of rough fish was desirable.

Then a new type of fishing gear--the snagline--made its appearance in Wilson Reservoir (then 17 years old). From August 1941 to July 1942, 25 snagline fishermen took more than 600,000 pounds of spoonbill, a species thought to be too rare to support a fishery. This new development gave the fishing industry a real boost. The expanded use of snaglines yielded a large quantity of meat at a time when it was greatly needed. But the snagline is highly selective; it takes very few scaled fish. The less desirable buffalo, carp, and drum kept right on increasing, their harvest prevented by legislative restrictions.

Later Post-Impoundment Fishing, 1945-52

In 1945 the Alabama Legislature liberalized fishing regulations by permitting the use of nets and seines. This automatically increased the catch of rough fish. However, only a small percentage of the reservoir area can be fished with nets and seines. Most commercial fishermen are not equipped to fish the deep open waters. Many of the shallow backwater areas are so full of stumps and other snags that it is quite impossible to use seines.

Commercial fishermen inevitably catch some game fish. But the majority of them are law-abiding citizens and take few game fish. The few who do not play fair are small-time operators for the most part, working with very limited tackle.

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Table 1 shows the commercial fish catch for Guntersville, Wheeler, Wilson, and Pickwick Reservoirs from 1943 to 1952.

Rebirth of the Mussel Industry

It was generally thought that when the dams were built on the Tennessee River, the musseling industry would be destroyed. This belief was so strong that no attempt was made to harvest mussels from Wheeler Reservoir until 1945, 9 years after impoundment. That year three former mussel diggers, then unemployed, decided to investigate the old mussel beds. They were amazed to find that the mussels had not disappeared but were actually thriving.

Almost overnight the industry revived, and now it furnishes part-time employment for approximately 100 persons. In 1951, diggers in the north Alabama area had an income of around $100,000. The shell that is most plentiful in the catch is commonly called the pigtoe. This is a thick shell, very much in demand for the manufacture of self-shank buttons for uniforms. Most of the shells are shipped to Muscatine, Iowa, to be processed, but several cutting plants are now operating in the Tennessee Valley.

The U. S. Fish and Wildlife Service is interested in mussel propagation and recently began a local project to find out which fish are host to the pigtoe shell.

Table 2 shows the annual harvest of mussel shells in the north Alabama reservoirs for the calendar years 1945 to 1951.

Present Trends in Relation to the Sport Fishery

The repeal of the Sanford Act in 1945 by the State of Alabama was not accepted wholeheartedly by the sport fishermen in the State. Since its repeal there has been persistent agitation by a group of ill-advised sportsmen to have the liberalized commercial fishing regulations totally abolished. Many of the most vociferous sportsmen still prefer to "sit and cuss" rather than to accept the invitation of the fishery research workers to seek out the answers through actual field investigations.

Throughout the Nation as a whole, and particularly in the Tennessee Valley, it is generally recognized that sport fishing is big business. The value of the sport fishery in the Tennessee Valley has been conservatively estimated at 10 to 12 million dollars a year. This estimate does not, of course, represent the actual value of the fish caught; it represents rather the business generated by the fishermen's purchase of fishing tackle, boats, and motors, also their purchase of gasolines, lodging, and meals while on fishing trips. From a monetary standpoint as well as from a recreation and health standpoint, the game fish in the TVA impoundments are a more valuable business asset than the commercial species. They occupy and serve the interests of a far greater number of people. According to our best estimates, the sport fishery in the Valley has at least 15 times the business value of the commercial fishery. As for investment per pound of fish, the sport fisherman spends much more money than the commercial fisherman.

These appear to be valid reasons why the sport fishery in TVA impoundments should receive preference over the commercial fishery. However, since nongame species are present, the sensible and practical thing to do is to allow commercial fishermen to harvest them for the market. By so doing, several hundred people in the north Alabama area will continue to have employment and, at the same time, accomplish the following desirable ends:

1. Make available several million pounds of high protein food, thus adding

TABLE 1.—Commercial fish catch: Guntersville, Wheeler, Wilson, and Pickwick Reservoirs

Fiscal year	Species						Total pounds	Total value
	Spoonbill	Catfish	Drum	Carp	Buffalo	Sturgeon		
1942-1943[1]	288,295	81,190	290	9,010	6,605	-	385,435	$ 62,409.00
1943-1944	393,060	355,930	10,040	15,435	26,400	1,875	802,740	133,551.00
1944-1945	117,735	468,050	26,215	34,280	100,775	1,100	748,155	140,193.00
1945-1946	114,665	561,750	49,400	90,100	141,100	3,400	960,415	168,379.00
1946-1947	151,555	626,970	49,995	97,940	181,310	8,565	1,116,335	236,976.80
1947-1948	138,675	712,025	66,175	117,250	223,050	5,540	1,262,715	320,390.50
1948-1949	165,100	760,080	58,400	190,200	293,600	8,500	1,475,880	369,520.00
1949-1950	143,475	819,300	67,700	141,850	272,050	5,850	1,450,225	365,072.50
1950-1951	126,880	878,600	120,200	174,175	331,350	4,300	1,635,505	414,666.50
1951-1952	104,850	1,127,850	86,600	204,200	363,000	7,750	[2]1,946,675	472,703.50

[1] January 1-June 30, 1943. [2] The total for all TVA lakes is probably close to 4 million pounds.

essential minerals and vitamins to the diet (this is doubly important during periods of national emergency).

2. Maintain a profitable industry which utilizes unskilled labor.

3. Make fuller use of the productive capacity of the waters.

4. Provide better sport fishing by reducing intraspecific competition for food and space.

Commercial fishermen should not be allowed to take over the fishing spots especially favored by the anglers. This applies particularly to the tailwaters below the dams where game and pan fish concentrate. Destructive types of gear should be prohibited except under supervision within known concentrations of nongame species. And, of course, all game fish should be returned to the water.

The white crappie is the principal species taken by anglers in the TVA impoundments in northern Alabama. Many sportsmen who oppose commercial fishing have claimed that this species has declined in number during the past 6 years. The scientific evidence available does not support this claim. The unit catch of crappie from 1945 to 1951 has shown a slow but gradual increase.

Fish harvesting studies on Wheeler Reservoir since 1945 and on Guntersville Reservoir since 1948 indicate continuous poor harvesting of the sport fish crop. Of 7,157 fish tagged on Wheeler Reservoir between 1945 and 1952, only 116 tags have been returned (1.6 percent harvest). The over-all picture on Guntersville is little better. Of the 7,249 fish tagged there between 1948 and 1952, only 164 tags have been returned (2.3 percent harvest).

In conclusion, the question of whether or not to permit the increased use of various types of commercial fishing gear should be thoroughly investigated before any drastic changes are made. This is true of all problems that deal with the utilization and conservation of biological resources. Those who have access to the facts are of the opinion that netting does not harm the sport fishery. It may actually be beneficial because it tends to maintain a more desirable relationship between the rough- and game-fish populations.

TABLE 2.--Showing the annual harvest of mussel shells in north Alabama Tennessee Valley reservoirs for the calendar years 1945 to 1951

Year	Mussel shells (tons) White	Pink	Total (tons)	Value (slugs and pearls)	Value
1945	200	20	220	$ 300.00	$ 8,660.00
1946	1,100	175	1,275	1,500.00	48,781.50
1947	1,440	170	1,610	6,500.00	85,540.00
1948	2,663	-	2,663	-	115,229.00
1949	1,570	-	1,570	-	54,950.00
1950	3,135	-	3,135	-	94,050.00
1951	2,491	-	1/2,491	-	99,640.00

1/ The total for all TVA lakes is in excess of 10,000 tons.

CASING FOR LEAD LINE ON GILL NETS

The setting of gill nets has frequently been hampered by tangles resulting from falling leads. At the Miles City (Montana) Station of the U. S. Fish and Wildlife Service, such delays are avoided by sewing a strip of nylon bobbinet (4 inches wide and as long as the net) to the bottom of the net so as to form a casing over the entire lead line. R. W. Branum, superintendent, reports that a 2-hour sewing job has saved a considerable amount of time and temper.

ASPHALT ROOFING PAPER ON HATCHERY FLOOR

The danger of slipping on the concrete floor of the hatchery room has been largely eliminated at the Lake Mills (Wisconsin) Station of the U. S. Fish and Wildlife Service by the laying of asphalt roofing paper that has small stones imbedded in it. N. J. Sears, superintendent, reports that this paper has been cut to size and fitted about the pipes, coated on its reverse side with a plastic roofing adhesive, and laid on thoroughly dry concrete. This floor covering washes easily with a hose and is expected to last about 10 years.

A SALMON RESEARCH LABORATORY

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THE NEWEST UNIT of the Section of Inland Fisheries, Branch of Fishery Biology, U. S. Fish and Wildlife Service, is the Salmon Biochemical and Nutritional Laboratory, located near the small town of Willard, approximately 60 miles east of Vancouver, Washington.

As the name implies, the prime function of this laboratory will be to carry on a rigorous research program to determine the basic nutritional requirements of salmon fry.

In view of the increasing demands on available supplies of diet components, and the partial inadequacy of existing production diets, the need for a better understanding of the dietary requirements of salmonoid fishes becomes obvious. By establishing test diets, that is, diets that are of a known chemical composition, the qualitative and the quantitative requirements for vitamins, amino acids, fats, carbohydrates, and minerals may be established. On the basis of the knowledge gained from these test diets, it should be possible to formulate more adequate diets composed of other available animal and plant byproducts.

In conjunction with this program, members of the staff will undertake biological and biochemical research, within their respective fields, utilizing salmon fry as the experimental animal.

The hatchery will contain 42 small troughs and 16 circular tanks (6 feet in diameter). Water is supplied from the Little White Salmon River and from a large spring. It will be possible to use water from either source separately or in combination. For studies to determine the effect of mineral content and to establish the mineral requirements, it will be possible to deionize--remove all minerals--from either water source while in constant operation. For the purpose of studying temperature effects, it will be possible to control within 1° C. the temperature of water entering individual troughs.

In the metabolism room, facilities are available for much finer controlled temperature work. This room is so designed that the temperature differential between the water in the trough and the room atmosphere is less than 1° C. A constant temperature may be obtained at any point between the temperature of the river or spring water and 100° C. In addition to the four small experimental troughs, there is laboratory space available for metabolism studies requiring constant temperature conditions.

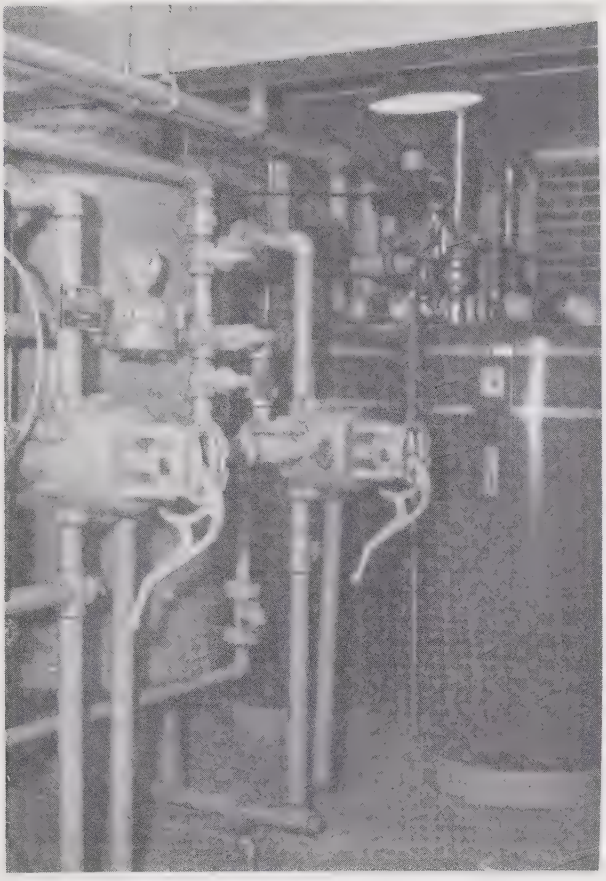
The main laboratory will be equipped with many of the most modern instruments for thorough investigations in protein, carbohydrate, fat, vitamin, and mineral chemistry. Plans for the future include facilities for radioactive tracer studies.

For safety precautions, a separate room is available for ether and other combustible solvent extractions.

Since many nutritional deficiencies are manifested by unique changes in the cellular structure of tissues, a small laboratory has been set up for this investigation. Tissues from normal and test fish will be imbedded in paraffin or frozen and then sectioned and stained to see whether any differences have developed during the test period. These stained and unstained mounts will then be examined, with both phase and ordinary light microscopes, for any pathological syndromes. Equipment and instruments will be available to carry on the most recent techniques in imbedding, sectioning, staining, and histological analysis.

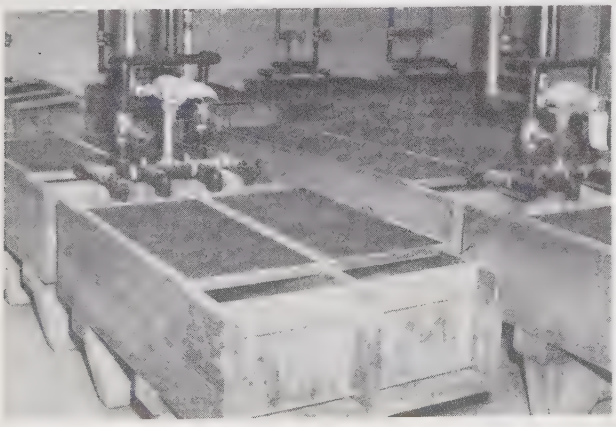
To make permanent records of all work, a laboratory has been equipped for photomicrography, as well as for other photographic needs.

The library maintained at this laboratory will contain the most recent editions of reference books on biology, biochemistry, chemistry, microbiology, histology, pathology, nutrition, and other allied fields. Subscriptions to foreign and domestic journals and periodicals dealing with these subjects will also be available.



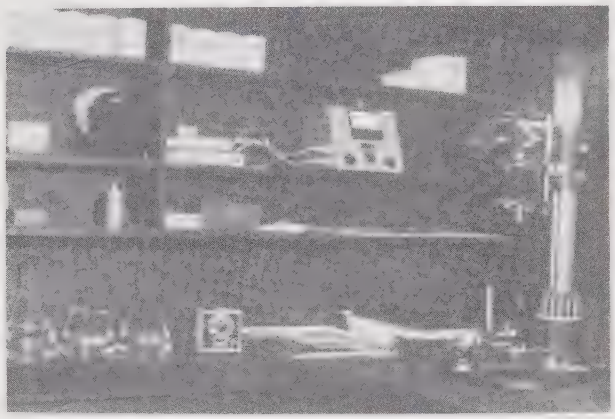
ABOVE: Left foreground: Deionizing tanks, of which there are four operating as two separate units. Background: Two heat exchangers for water temperature control to hatchery troughs.

BELOW: A section of troughs in the hatchery room. The black pipes contain deionized water; outer pipes contain untreated water. The large central valve (light-colored) is a mixing valve for temperature controls.



ABOVE: One side of central bench in main laboratory.

BELOW: One side of photolaboratory. On the right is a photomicrographic camera.



The permanent staff of this laboratory will be representatives of the U. S. Fish and Wildlife Service. These staff members will include a protein chemist, a lipoid and carbohydrate chemist, an analytical chemist, a nutritionist, a histologist, a microbiologist, a fishery biologist, and laboratory aids. Facilities at the laboratory are available also for personnel of other research organizations and for graduate students from various universities that are interested in this field of research.

The Salmon Biochemical and Nutritional Laboratory will probably be in full operation by early summer. A cordial invitation is extended to those who may desire to inspect these facilities and to discuss particular problems with members of the laboratory staff.

THE EFFECT OF ETHER ANESTHESIA ON FIN-CLIPPING RATE

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AS PART OF AN EXPERIMENTAL PROGRAM to learn the effects of stocking lake trout (Salvelinus namaycush) in Lake Superior, 141,392 fingerlings were marked at the Charlevoix (Michigan) Station of the U. S. Fish and Wildlife Service in October 1952. The adipose fin was removed from all fish, the right pelvic from about half (70,869), and the left pelvic from the remainder (70,523). A random sample of 2,417 of the fish showed an average total length of 4.0 inches (range, 2.7 to 5.4). The mean weight of all fish marked was slightly less than one-third ounce (49 fish per pound).

Ten local women, none of whom had previous experience in the work, were employed to mark the fish. Bone-cutting forceps were used for excision of the fins, and each worker wore a bobbinet glove to facilitate handling of the fish, as suggested by Hallock, Warner, and Fry (1952). On alternate days the fish were anesthetized with ether before marking, to determine the effect of its use on the fin-clipping rate.

This use of an anesthetic for quieting fish is a commonly employed field technique. Griffiths, Webb, and Schneider (1941) noted advantages in the use of ether anesthesia in handling fingerling and adult steelhead trout. Foster (1941) stated that five or six anesthetized spotted trout fingerlings could be marked in the time that ordinarily would be spent maneuvering a single active fingerling into the desired position, but he gave no supporting data. Gerking (1949) reported that urethane was helpful in working with large numbers of live fish which have to be handled individually.

In the present study each operator began work (on days when ether was used) with a 1-percent aqueous solution of the anesthetic. This concentration provided a satisfactory level of anesthesia at the prevailing water temperature (56° F.). About 2 quarts of the solution was placed in an enameled basin. Each worker was supplied with a small bottle of ether, for use as required, to maintain a suitable concentration for anesthesia. The individual usage varied, but for most workers the concentration of ether used probably ranged between 0.5 and 1.5 percent. In marking, a small scap net was used to remove the lake trout, in lots of 10 to 25 or more, from the hatchery trough. The bag of the net was suspended in the anesthetic, and the net frame was held by the rim of the basin. Fish were removed singly, marked, and returned to fresh water.[1/] On days when ether was not used, the small lots of fish were not removed to a separate container; on these days the fish were held for marking in a scap net suspended in the trough. Otherwise the marking procedures were identical.

The data in table 1 show the average number of fish marked per hour each day and by each operator, as well as the change in rate from the preceding day. Marking (without ether) was begun on the afternoon of October 20, which served largely as a period of instruction. During the remainder of the experiment most of the markers worked 8 hours each day except October 25 (when they worked 4 hours) and October 27 (when they averaged 5 hours). On the latter date four of the markers were assigned to other duties. Ether was used on alternate days, beginning on October 22.

As a grand average, the lake trout were marked at a rate of 339 per hour. The range among individual workers was 287 to 436, and the average for the group ranged from 207 per hour during the first half-day to 484 (6 operators working) on the last day of work. With one exception (Operator 2, October 27), the average hourly rate for each worker was higher on each day that ether was used than on the preceding day. With three exceptions (Operator 1, October 23; Operators 2 and 6, October 25), the average rate decreased when

1/ Half of the workers preferred to work without bobbinet glove when marking fish which had been anesthetized.

TABLE 1.--Numbers of fingerling lake trout marked per hour, Charlevoix Hatchery, October 20-27, 1952

Operator number	Date: October 20 — Number of fish marked per hour	October 21 — Number of fish marked per hour	Change	October 22 (ether) — Number of fish marked per hour	Change	October 23 — Number of fish marked per hour	Change	October 24 (ether) — Number of fish marked per hour	Change	October 25 — Number of fish marked per hour	Change	October 27 (ether) — Number of fish marked per hour	Change	October 20-27 — Average[1] number of fish marked per hour	Percentage of marks acceptable
Left pelvic and adipose fins clipped:															
1	219	320	+101	397	+77	418	+21	570	+152	...	...	[1]/640	+70	436	99.6
2	240	281	+41	387	+106	381	-6	475	+94	482	+7	434	-48	386	99.0
3	202	216	+14	410	+194	289	-121	423	+134	293	-130	...	...	320	99.9
4	169	183	+14	361	+178	294	-67	412	+118	317	-95	458	+141	319	94.9
5	186	213	+27	345	+132	268	-77	405	+137	330	-75	...	...	301	97.0
Average,[2] left pelvic	203	242	+39	378	+136	330	-48	457	+127	355	-102	511	+156	351	98.1
Right pelvic and adipose fins clipped:															
6	245	278	+33	368	+90	357	-11	387	+30	414	+27	501	+87	367	99.1
7	164	240	+76	370	+130	362	-8	413	+51	402	-11	492	+90	356	98.9
8	248	218	-30	365	+147	310	-55	372	+62	346	-26	...	...	314	96.6
9	203	166	-37	351	+185	271	-80	383	+112	311	-72	388	+77	297	99.7
10	191	201	+10	323	+122	281	-42	363	+82	318	-45	...	...	287	97.9
1	...	...	...	...	...	...	...	...	...	382	...	[1]/485	+103	416	98.2
Average,[2] right pelvic	210	221	+11	355	+134	316	-39	384	+68	362	-22	467	+105	328	98.5
Grand average[2]	207	232	+25	366	+134	323	-43	420	+97	359	-61	484	+125	339	98.3
Total number of fish marked	6,197	18,521		27,832		25,848		33,612		14,376		15,006		141,392	
Percentage of marks acceptable	93.2	96.2		98.2		98.4		99.6		98.9		100.0		98.3	

[1]/Operator No. 1 marked some fish from both lots on October 27.
[2]/Averages were determined by dividing total fish marked by total hours worked.

the anesthetic was not used. Statistical analysis of the data[2/] showed that, after adjustment for daily improvement due to experience, the improvement attributable to the use of ether was of considerably greater magnitude than could be explained by chance variation ($p < 0.001$). The average hourly rate during the period was approximately 75 to 100 marks per hour more on days when ether was used than could be expected from the performance on days when the anesthetic was not used (or an increase in rate of about 28 percent). The use of ether appeared to help the poorer operators most. (There was no significant difference in rate between the operators who clipped the left pelvic fin and the operators who removed the right pelvic fin, irrespective of whether ether was used.)

A total of 97.8 percent of the marks made without the use of ether (after the preliminary instruction period of October 20) and 99.2 percent of the marks made on anesthetized fish, was judged acceptable. These percentages were determined by the examination of a total of 96 samples of 100 fish each (one sample during each 4-hour work period of each employee). Although there was some improvement with experience, the quality of the work was generally high throughout the operation. Different amounts of coaching were given to various operators as the work progressed, so that evaluation of the precise effect of the anesthetic on quality of work is difficult. However, the slight differences observed in quality of mark tended to favor the use of the anesthetic.

Post-fin-clipping mortality was slightly higher among fish marked with ether than among fish handled without anesthesia, but the difference was too small to be of practical importance. A total of 24,729 fish clipped without anesthesia and 27,832 fish on which ether was used, had mortalities (within 2 weeks after marking) of 0.15 and 0.22 percent, respectively. Total post-marking mortality for the entire operation (prior to transfer of the fish, 9 days after completion of the work) was 0.20 percent.

The data recorded during this brief experiment indicate that the use of ether anesthesia was decidedly advantageous in the marking of fingerling lake trout.

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[2/] The data were analyzed by Mr. George F. Lunger, formerly statistician on the staff of the Great Lakes Fishery Investigations. The methods used are discussed by Rao (1952: 75-128).

CELLULOSE NITRATE SHEETS PRACTICAL FOR HATCHERY NOTE-TAKING

Accurate records of mortality, feeding, and spawning data require that fish-culturists jot down notes and figures while working with the fish and correlate the information later. The difficulty has been to keep these notes and figures legible despite the hazards of water splash, wet hands, and wet or moist tools until permanent records can be made.

From the Coleman (Anderson, California) Station of the U. S. Fish and Wildlife Service, John Pelnar reports that notes and figures are easily made with ordinary pencil lead on cellulose nitrate sheets whether wet or dry, and that these data remain legible until they are removed with soap and cleanser. Coated with opaque celluloid, these sheets (0.02 inch in thickness) may be used again and again. If wanted, guide lines and headings may be put on the sheets with waterproof ink which will not wash away.

FURTHER DATA ON THE DEVELOPMENT OF A NONMIGRATORY STRAIN OF RAINBOW TROUT

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A GROUP OF FISHERY WORKERS attending the meetings of the American Fisheries Society at Memphis, Tennessee, in 1950, planned a research program for the development of a nonmigratory strain of rainbow trout.

These workers agreed that, as in brown and brook trout, there are hereditary differences in the several strains of rainbow trout that are now being produced and that have been developed through selective breeding in the United States. They also agreed upon the suggestion made by Dr. A. S. Hazzard, Director of the Institute for Fisheries Research at the Michigan Department of Conservation; namely, that it would be desirable to have the U. S. Fish and Wildlife Service work with the States in a study of the migratory habits of rainbow trout used to develop inland trout fishing.

Unfortunately, few, if any, records have been maintained for the various strains of fish produced by hatcheries in the United States. So far as is known, no fish-cultural output carries any pedigree or warranty as to strain. Moreover, no comprehensive studies have been made to determine the actual characteristics of the supposed "strains." Where would animal and plant husbandry be if such a course of action had been pursued?

For the basis of its work in developing a nonmigratory strain of rainbow trout, the group meeting in Memphis decided to use rainbow trout stock produced at the Manchester, Iowa, Station of the U. S. Fish and Wildlife Service.[1/] The following States undertook to participate in the necessary experimental work: Maryland, Michigan, New York, North Carolina, and Wisconsin. The Service set aside 50,000 eggs, shipping 10,000 to each cooperator during December 1950 or January 1951.

The group agreed that the work started in 1951-52 would be preliminary in nature, and an effort would be made to obtain accurate records after planting. All of the Manchester trout would be marked before being planted. Because angling has been the major cause for disappearance of rainbows more than 7 inches long, an effort would be made to plant a number of the trout in waters closed to angling. So that the trout might be able to migrate freely, the streams selected for planting would contain no barriers. Where fishing was permitted, a creel census would be desirable. If, after several years, it was determined that some of these fish had never migrated, it would then be desirable to obtain eggs from these surviving fish for further experimentation. Similar studies could be made with any strain of the several trout species commonly reared in hatcheries. It would be a forward step in fish culture if all States would institute such a project.

To date, North Carolina is the only State that has submitted a full report on its phase of the experiment. This report, by Ratledge and Cornell, has been published in full on pages 57 to 63, inclusive, of this issue of THE PROGRESSIVE FISH-CULTURIST.

Reports from other States are summarized:

Maryland. Fingerlings (2,500) were planted in North Branch of the Casselman River, Poplar Lick Run, and Cherry Creek, all in Garrett County. Because of the pressure of other projects, it has been impossible to determine the success of these plantings. The first check will be made early in 1953.

Michigan. All of the first shipment of eyed eggs died en route from Manchester, Iowa.

[1/] The group considered several sources of stock, including Furnace Brook, Vermont; Manchester, Iowa; and Wytheville, Virginia. The group decided not to use the Furnace Brook trout for this project because of the difficulty in obtaining brood stock and eggs and because of the presence of falls which act as a barrier in the stream. Of the two stocks available from the Federal hatcheries, the group preferred the Manchester fish because the stock has been kept intact for approximately 30 years—and there is some possibility that the Wytheville stock originated at Manchester.

The second shipment was received in good condition, and the hatch was successful, but growth was slow and irregular. In the spring of 1952, the survivors were marked by removal of a fin and were being held at the hatchery for planting the next day. When an employee closed--and forgot to open--the water inlet to the tank containing the fish, all fish died.

Wisconsin. In June 1952, 450 Manchester rainbow and 450 ordinary rainbow yearlings were stocked in the Little Brule River. The Manchester trout were marked by removal of the left pectoral fin; the other rainbows, by removal of the right pectoral. On October 27, 1952, in a shocker survey made from the upper limits of possible migration (where the fish were planted) to a point 1-3/4 miles downstream, the recoveries were 4 Manchester and 5 ordinary rainbow trout, plus 55 unmarked rainbow, 109 brook, and 607 brown trout. The section of stream had been closed to angling. Whatever the cause for the poor return of marked trout, apparently the two types of rainbow trout were equally affected. The stocked rainbows may have (1) migrated downstream or (2) suffered a high mortality. Many workers have shown a poor survival of hatchery trout. Here, the marked rainbow trout would have suffered a mortality of 99 percent in 4 months. Possibly both migration and mortality were responsible for the low returns.

New York. Three streams were chosen for this experiment: Eaton Brook in Madison County, Canasawacta Creek in Chenango County, and Cherry Valley Creek in Otsego County. In October 1951, 9,500 fingerling rainbow trout were scatter-planted in these streams. Half (4,750) were Manchester trout; the remainder were New York (Caledonia) trout. The fish were marked by removal of a fin. The recovery operation was conducted in July and August 1952 (8 to 10 months after planting) with an electric shocker. As they were still under legal size, these fish had not yet begun to appear in fishermen's creels. It was estimated that between 60 and 85 percent of the stocked sections were covered in the population study. Of the 9,500 marked fish planted, only 116 (slightly more than 1 percent) were recovered; and of the recoveries, 69 were New York rainbows and 47 were of the Manchester stock. In each of the three streams, New York rainbows were recovered in greater numbers than Manchester fish. It is not known whether migration, natural mortality, angling mortality, or a combination of these factors is responsible for the difference in recovery. The New York rainbows were slightly larger than the Manchester fish when planted, and this may have resulted in a better survival.

From the foregoing information it is apparent that there was virtually no difference in the migration of the Manchester strain of rainbow trout and other strains used as controls in these experiments. It is obvious, also, that some of the experiments were not too carefully planned or conducted. A few of the causes for the poor returns are listed as follows:

1. Time of planting and water temperature. E. L. Cooper found (abstract, THE PROGRESSIVE FISH-CULTURIST, 15 (1): 45-46) that rainbow trout exhibited an immediate downstream movement if planted when water temperatures were below 50° F. Little movement was shown when water temperatures were above 50° F.
2. Better survival is obtained when fish are planted in the spring, and highest mortality results from fall planting.
3. Inadequacy of these population studies.
4. Competition with other species, including trout, for food and space. Perhaps more care should have been given to the selection of streams used in the experiments.

It is recognized that any rainbow trout stocks may have latent migratory qualities. Therefore, in experiments of this kind, production would have to be tested carefully with marking studies before it could be determined that the fish would "stay put" and breed in the streams where they were planted. Differences, if any, which develop over a longer period would be difficult to test because the samples would be expected to be much smaller as time went on. It becomes obvious that many studies must be made in order to develop a nonmigratory strain of rainbow trout. These studies will take much time and require accurate records and many checks after planting.

Many fishery workers may not agree that studies like this are worthwhile. We, however, shall be happy to coordinate further experiments of this type and to give all assistance possible. Also, we solicit any criticisms and suggestions about work that has been done and about continuing studies. After all, some fishery workers have shown too much interest in getting fish out of the hatchery and too little interest in determining the success of the plantings and the best means of improving fish stocking.
--The EDITORS.

A MODIFICATION IN THE TECHNIQUE OF COMPUTING AVERAGE LENGTHS FROM THE SCALES OF FISHES

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IN VIRTUALLY ALL THE STUDIES that employ scales, otoliths, or bony structures to obtain the growth history of fishes, it has been the custom to compute lengths for each individual fish and from these data obtain the average growth rates for any particular group. This method involves a considerable amount of mathematical manipulation, time, and effort. Theoretically it should be possible to obtain the same information simply by averaging the scale measurements for each year of life and the length of the fish employed and computing the average lengths from these data. This method would eliminate all calculations for individual fish. Although Van Oosten (1929: 338) pointed out many years ago the validity of this method of computation, his statements apparently have been overlooked by subsequent investigators.

The accuracy of the suggested method is demonstrated here for four species in table 1. In this table two series of computed average lengths are shown for each species. The one (averages) was based on the average measurements of scales (diameter or radius); the other (individuals), on the growth calculations of each individual fish. It may be observed at a glance that all corresponding values in any two comparable series are either identical, as they should be, or differ to an insignificant degree. The obvious conclusion is that the use of average scale measurements for calculating average growth rates of fishes is valid.

Attention should also be called to another recent development of interest to those who compute growth rates of fishes from their scales. In the past, standard lengths in millimeters of fish at capture were generally employed for computations of growth, as the theory assumes that the growth of only the scaled portion of a fish's body is reflected in the growth of its scales. However, as neither the fishery administrators nor the general public in this country (and to this could perhaps be added "fishery biologists"!) have a clear conception of either the standard length or the metric system, the modern tendency has been to convert these measurements to total lengths in inches. This procedure requires that both standard and total lengths be obtained in the field or the laboratory, or that a conversion factor be applied to the standard lengths.

It is of interest, then, to determine whether the direct employment of total lengths

TABLE 1.--Comparisons of calculated lengths based on the averages of scale measurements (averages) and on the computations of growth of each individual fish (individuals)

Species	Locality and date	Age group	Number of fish	Length at capture	Based on	Calculated average lengths for year 1	2	3	4	5
Sheepshead	Lake Erie (Ohio) Aug.-Nov., 1927	V	33	292 (S.L.)[1/]	Averages	93	154	196	242	270
					Individuals	93	155	192	242	269
Lake herring	Bay City, Mich. Nov. 1, 1922	V	95	241 (S.L.)	Averages	114	171	205	229	...
					Individuals	114	171	205	229	...
Lake trout	Menominee, Mich. May 10, 1932	III	159	11.71 (T.L.)[1/]	Averages	3.48	7.64	11.35	...	...
					Individuals	3.49	7.64	11.32	...	...
White bass	Huron, Ohio Aug. 10-28, 1928	II	246	206 (S.L.)	Averages	91	169	...	...	...
					Individuals	91	169	...	...	...

[1/] S.L. = average standard length in mm.; T.L. = average total length in inches.

TABLE 2.--Comparisons of calculated total lengths derived from the actual total lengths at capture and scale measurements (T.L.) and from the conversion of the average standard lengths (C.T.L.)

Species	Locality and date	Age group	Number of fish	Kind of length	Length at capture	Calculated average lengths[1] for year 1	2	3	4	5
Sheepshead	Sandusky, Ohio Sept. 26-30, 1927	V	21	S.L.[2] (mm.)	303	94	156	200	248	277
				T.L.[2] (inches)	14.87	4.61	7.62	9.81	12.14	13.60
				C.T.L.[2] (inches)	14.88	4.62	7.66	9.82	12.18	13.60
Lake trout	Charlevoix, Mich. July 30, 1932	IV	72	S.L. (mm.)	303	71	146	205	254	...
				T.L. (inches)	14.18	3.34	6.82	9.62	11.92	...
				C.T.L. (inches)	14.18	3.33	6.84	9.60	11.90	...
White bass	Sandusky, Ohio Oct. 12, 1927	I	366	S.L. (mm.)	172	79	...	...	...	...
				T.L. (inches)	8.53	3.95	...	...	...	...
				C.T.L. (inches)	8.54	3.92	...	...	...	...

[1]The calculated lengths have not been corrected for disproportional growth of body and scale. The same correction cannot be used for S.L. and T.L. A body-scale relationship line drawn on a chart would have a higher point of intercept on the length axis for total than for standard lengths.

[2]S.L. = standard length in mm.; T.L. = total length in inches; C.T.L. = S.L. converted to T.L. in inches (conversion factor for sheepshead = 0.04911; for trout = 0.04685; for white bass = 0.04968).

in inches gives us the same calculated results as the use of converted standard lengths. It is true, standard lengths include the length of the head, which, like the tail, is not involved in the body-scale growth relationship; but this factor has been ignored by nearly all investigators in the past, although Van Oosten (1929) showed that in the shallow-water cisco (lake herring) the length of the head was not an important variable in the body-scale length ratios. Perhaps the length of the tail may likewise be ignored and total lengths, instead of standard lengths, be employed for studies of growth in fishes. If this direct use of total lengths is valid, it, like the employment of average scale dimensions, would save a considerable amount of time and effort of our research personnel.

Table 2 compares for three species the calculated total lengths derived by the two methods of computation. The one series (T.L.) was based directly on the actual total lengths at capture and scale dimensions of each individual fish (except in the white bass, where average scale measurements were used); the other (C.T.L.) was obtained by converting the average standard lengths by means of a factor obtained from the total-standard length ratio of the age groups. It is obvious from table 2 that the difference between any two corresponding values of the comparable series of total lengths is consistently small and insignificant. It is concluded, therefore, that total lengths may be computed directly from total-length measurements of fish, thus eliminating the necessity for also obtaining standard lengths. A correction for disproportionate growth of body and scale can be applied to the averages of total, as well as of standard, lengths by the use of the same general formula (Van Oosten 1929: 338).

The suggested methods of computing lengths proposed here will save a great amount of work, for they should be applicable to all species of fish. After all, they are basically matters of simple mathematical ratios. There remained only the need of demonstrating their validity by the application to actual biological data.

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APPARATUS AND METHODS FOR THE COLLECTION OF ATTACHMENT MATERIALS IN LAKES

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THE PRODUCTIVITY OF WATERS has long been, and continues to be, the primary concern of limnologists. Various indices of productivity have been developed as the result of numerous long-term investigations in North America and Europe, and certain of the most prominent ones have been used to delimit and group lakes according to type. These indices stress the importance of organic productivity but recognize the difficulty of obtaining precise measurements and the importance of a thorough understanding of the complex interrelationships of all components of the aquatic environment.

One of the most recent approaches to an understanding of the problem has been work on attachment material or periphyton, as defined by Young (1945), "that assemblage of organisms growing upon free surfaces of submerged objects in water ..." This material is a basic component of aquatic biota and includes such living forms as--to name a few--bacteria, algae, protozoans, rotifers, and bryozoans. Pioneer work in this field was done by Hentschel (1915), who measured the material growing on exposed glass slides and on aquatic plants. This has been followed by sporadic work in the intervening time. Notable contributions have been made in recent years by Young (1945), Clarke (1946), Newcombe (1949, 1950), and others. These workers have developed apparatus and techniques, have pointed out certain difficulties and limitations of present methods; but, of most importance, they have demonstrated that the method has great promise as a valid measurement of the productivity of standing waters. Considerable additional work is needed, however, in order to appraise its utility more accurately.

For the past three summer seasons (1950, 1951, 1952), fishery research biologists of the California-Nevada Inland Fishery Investigations of the U. S. Fish and Wildlife Service have been studying the productivity of alpine and montane lakes in Convict Creek Basin of the Sierra Nevada Range of eastern California. Eleven lakes are situated in this drainage basin. They exhibit a wide range in their physical, chemical, thermal, and biological conditions, as determined by a detailed study of these characteristics in 1950 and 1951.

In 1952, it was proposed to make a thorough investigation of the attachment materials in these lakes; but, because of the severity of the 1951-52 winter, the field season was limited to less than one-half of its usual duration. Consequently, it was impossible to carry out the planned program according to schedule. Work was limited to collections from four lakes and to the design and testing of collecting apparatus and techniques.

The collection of attachment materials in lakes requires the simultaneous exposure of groups of plates suspended at various depth strata. The collecting surfaces or plates must be smooth, hard, inert to chemical and physical influences, and of dimensions which permit ease in handling and measurements. For accurate quantitative results, the entire areas of both flat surfaces of the plates should be exposed, and this requires supports that minimize contact with extraneous materials and lessen interference with light and growth of attachment materials. The support should permit orientation of the plate in vertical position so as to minimize the collection of inorganic sediments and abioseston, material which tends to accumulate on the exposed surfaces of the collection plates with periphyton. The suspension line for carrying the plate supports must be resistant to prolonged periods of immersion and must permit the grouping and distribution of collecting plates according to depth. Finally, the delicate nature of periphyton necessitates great care in the handling, storage, and transport of the exposed plates.

In order to satisfy these requirements, field apparatus and techniques have been

developed. The collecting apparatus (see figure 1) consists of a suspension line of multistrand, copper-steel conductor wire with overlay fabric and asbestos insulation; ordinary wooden spring-clip clothespins for plate holders or supports; standard microscope glass slides for exposure plates; a 1-gallon airtight metal container painted bright yellow for the float; and an anchor of sufficient weight to sink the float below the surface. Each clothespin slide support or holder is individually secured to the suspension line (figure 1, detail A-A) by passing a short length of copper wire through the spring eye of the pin and wrapping the free ends tightly around the line so that the clothespin is held in a rigid position at right angles to the line. In this manner, clothespins are fastened to the line in close-set groups of five at predetermined intervals depending on the depth of water and strata to be sampled. The holders and their grouping permit the double-surface exposure of four slides for quantitative analysis and one slide for qualitative analysis of the periphytonic material at each depth stratum. Two slides may be inserted into a clamp for single-surface exposure if desired. Handling of the slides must always be accomplished by touching only the edges, which are not considered in subsequent examination.

The suspension line is prepared in advance. A length which corresponds to the known depth of the lake at the desired point of collection is selected. The anchor weight is securely attached to one end of this line, and clothespins are secured at desired intervals in the manner described. The assembled portion of the apparatus, together with clean microscope slides and the float, is then ready for setting. This task requires the services of two men: one man lowers the line into the lake while the second man springs the clothespins and inserts the slides in a vertical, lengthwise position. When the anchor has come to rest on the lake bottom, the line is hauled up about 2 feet and the float is attached at this point. The entire apparatus is then lowered again. The buoy floats about 2 feet below the surface, minimizing the undesirable effects of wind and wave action on the set. Since the float is painted bright yellow, it can be located rather easily in small lakes. Sets in larger lakes should be located by two bearings from shore.

At the conclusion of the exposure period (25 to 30 days), the apparatus is carefully removed from the lake. This procedure also requires the services of two men: one man raises the line slowly while the other man removes the slides from their clamps and puts them--after they have been air-dried for several minutes--into storage boxes. Convenient storage boxes can be made from standard microscope slide boxes by replacing rectangular-slotted slide separators with ones having sharply cut V-notches. With this type of notch, the slides are held in position by the sharp corners of their edges without danger of interference with attachment material on the exposed slides. Soft rubber strips placed along the bottom and in the lid of the box will prevent movement of the slides when the box is closed. Adhesive or gummed tape can be used to seal the box against intrusion of dust or other foreign matter pending final analysis.

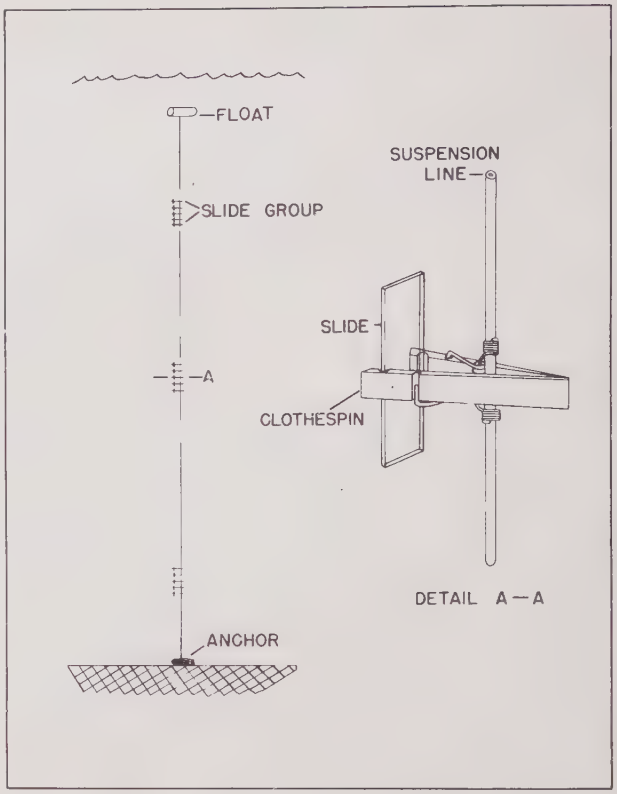

FIGURE 1.--Apparatus for sampling attachment material in lakes.

As stated, investigation of attachment material in Convict Creek Basin lakes was limited to collections from 4 of the 11 lakes in the drainage. Single sets with groups of slides at 2-foot, 15-foot, and 25-foot strata were exposed for 30 days in Lakes Genevieve, Edith, Cloverleaf, and X. These lakes are of glacial origin, and their basins occupy similar substrate materials. Some of their general characteristics are compared in table 1.

TABLE 1.--Comparison of certain physical and chemical characteristics of the lakes

Lake	Elevation (feet)	Surface area (acres)	Maximum depth (feet)	Transparency secchi disc (feet)	Total dissolved solids (ppm)
Genevieve	9,910	42.3	120	59	26.0
Edith	10,100	18.0	110	46	23.0
Cloverleaf	10,310	11.6	25	25 (bottom)	20.0
X	11,300	2.5	25	25 (bottom)	8.2

Four in each group of slides exposed at each depth stratum were dried in a thermostatically controlled electric oven for 16 hours at 60° C. The dry material was then carefully scraped from them, weighed, fired, and again weighed. Results of these analyses are summarized in table 2.

These data are by no means conclusive. They simply represent the results of trials that were concerned primarily with testing apparatus and techniques of operation in the field. They do, however, constitute an illustration of the feasibility and value of the method for measuring the productivity of lakes. Table 1 shows that these trials were made in two relatively small shallow lakes and in two relatively large deep lakes. The lakes differ considerably in elevation, surface area, and depth but are similar in clearness. Total mineral constituents are low in all but are comparable for Lakes Genevieve, Edith, and Cloverleaf and exceedingly low in Lake X. It will be noted that Lakes Genevieve and Edith are very similar in the general characteristics considered, and that they are comparable in total quantity of attachment materials produced and in percentage of organic and ash components. In contrast to the similarity of these lakes, the shallow lakes exhibited radical differences both in quantity of attachment materials and in percentage composition of the material in organic and ash fractions. It is suggested that these differences might be due to the paucity of dissolved minerals in Lake X and its extreme elevation. Even so, the quantity of attachment materials taken in Lake X is equal to that collected in the most productive of the larger lakes--Lake Genevieve.

The data confirm the productive advantages of small, shallow lakes and indicate the influence of elevation, depth, transparency, and quantity of mineral constituents in determining productivity levels. They also indicate that the method can provide a direct measurement of productivity with more reliability than other methods commonly used. It is certainly sensitive to a variety of conditions, but much more work must be done to establish its validity.

TABLE 2.--Comparison of attachment materials

Lake	Total dry material (weight[1/])	Organic matter (weight[1/])	Organic matter (percent)	Ash (weight[1/])	Ash (percent)
Genevieve	2.98	1.75	59	1.23	41
Edith	2.59	1.69	65	.90	35
Cloverleaf	25.98	18.23	70	7.75	30
X	2.98	1.47	49	1.51	51

[1/] Milligrams of material per square decimeter of slide surface; mean values for the sums of material from the three depth strata sampled.

Acknowledgment

All the staff members of the Convict Creek Experiment Station have contributed to the preparation of this article.

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INNOVATION IN A MACHINE FOR READING FISH SCALES

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LABORATORIES THAT POSSESS machines for reading fish scales or that contemplate building, purchasing, or improving such equipment, may be interested in innovations adapted by our laboratory.

The prohibitive cost of purchase was the primary factor that induced us to build our own machine. The laboratory fortunately possessed a Bausch and Lomb microprojector, and this was adapted to a wood cabinet constructed of 2- by 2-inch planed lumber which was rabbeted to take inserts of quarter-inch plywood for the front, sides, and back. The dimensions of the cabinet followed the essential details of the basic design described by Van Oosten, Deason, and Jobes (1934) and Lagler (1949: 69-71).

A striking improvement in the optical system was the evenly illuminated field on the viewing screen achieved through the use of an Ecta-lite field lens furnished through the courtesy of the Eastman Kodak Company. This lens has a diameter of 14 inches and a thickness approximating that of thin cardboard. Its flexibility required support, and this was provided by sandwiching the Ecta-lite lens between two panes of glass, with the one ground or frosted surface facing downward into the machine to minimize internal reflections. Use of the lens results in a brilliant, sharply defined, projected image. It also enables the individual operator to adjust the position of the projected image to the elevation of most convenient viewing, by sliding the lens up or down between the two pieces of glass. Figure 1 shows the cabinet with the circular Ecta-lite lens in place.

There being no flashed opal or frosted glass available in our city, a screen was constructed by hand-grinding one side of a pane of quarter-inch plate glass. Fine-grade, water-soluble, carborundum valve grinding compound was applied to the glass in small dabs. The glass was then flooded with a small quantity of water and ground with a fine carborundum stone applied in a circular motion. After an interval of grinding, the glass was washed and dried--and areas not sufficiently frosted were marked with further dabs of valve compound and the process continued. Approximately 45 minutes, total time, was required to complete the screen.

The side door in the cabinet is a useful addition. It enables us to adjust conveniently the vertical and horizontal traverse

FIGURE 1.-- View of scale cabinet with Ecta-lite lens in place.

FIGURE 2.--Detailed view of gear chain (with white sheet inserted under gear mechanism for photographic effect).

of the reflecting mirror so that all points of the fish-scale projector are registered in focus on the viewing screen. Actual adjustment is accomplished through projection of the image of a stage micrometer. Incidentally, the door provides easy access for dusting the mirror.

Ease of focusing the microprojector has been secured by extending an adjustment knob to the top surface of the cabinet through the gear chain of an ordinary hand drill. Figure 2 illustrates the method used. This drill is of the $1.98 variety and not the finely machined mechanism found in the projector. A universal joint constructed from an ordinary No. 8 rubber cork, with holes bored to accommodate 1/8-inch brass lugs, serves to adjust discrepancies between the projector and the hand drill.

The reading of scales does at times become a tedious operation, but the described cabinet helps to minimize physical fatigue and allows an almost enjoyable posture while the scales are being read.

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COD-LIVER OIL AND PRODUCTION COSTS

Nutrition studies at the Cortland Experimental Hatchery, Cortland, New York, have included studies on the desirability of providing cod-liver oil in the diet of trout. Dr. A. M. Phillips, Jr., of the U. S. Fish and Wildlife Service, has recently summarized the relation of cod-liver oil to production costs.

"The inclusion of cod-liver oil at the established level of 3 percent of the diet," reported Dr. Phillips, "has increased the rate of growth from 20 to 30 percent. The cost of the oil at this level is approximately 1¢ per pound of food. Assuming a total cost of 7¢ per pound for the standard diet and a conversion factor of 3 (pounds of food to produce 1 pound of fish), it would cost 21¢ to produce a pound of fish. If a 20-percent increase may be expected from the use of oil, the same amount of food will produce fish at a conversion rate of 2.5 pounds per pound of fish. The cost of this diet would be 8¢, giving a total cost of production (food) of 20¢ per pound. Aside from this saving, it would take only four-fifths as long to rear the fish to a given size and result in a great decrease in labor and handling costs.

"The total cost, of course, would depend upon the hatchery, its location, and efficiency of management."

FISH FOOD PELLETS SHOW PROMISE

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IN THE FORMULATION OF TROUT DIETS several aspects should be considered. Among these are the diet consistency, the size of particle, the ease of preparation, the conversion of food into fish flesh, the cost of production, and the mortality of the fish.

One of the first problems that confronted the fish-culturist when dry meals were added to the traditional meat diet, was the method of binding the ingredients to prevent the loss of dietary essentials in the water. In the early 1930's it was discovered that if 2 percent salt was added to freshly ground--and slightly frosted--pork spleen, the resulting mixture had a rubberlike consistency which served admirably as a binder for both dry meals and other meats, such as liver, in trout diets. These diets were fed with either a spoon or a modified potato ricer. The bound diet, as later developed for pond feeding, was mixed without the addition of water and was run through a centrifugal blower. This was later modified in that some water was added and the mixture was turned in a cement mixer. The size of the particles in these last two types could be regulated within limits by the number of times the material was put through the blower, by the amount of water added, and by the length of time the material was left in the cement mixer. These diets resulted in more efficient feeding of fish in ponds.

There appeared on the market, a few years ago, a dry fish food pellet which eliminated the mixing of meats and dry meals. These pellets were supplied in two sizes, the smaller (3/32 by 1/8 inch) for fish from 3 to 7 inches and the larger (3/16 by 1/8 inch) for fish 7 inches and longer. It was recommended that these pellets be fed by scattering over the pond, in much the same manner as one would feed corn to chickens.

The amount of pellets fed per day, in percent of the body weight, was based upon fish size and water temperature. However, the percentage recommended has changed considerably during the past 2 years. Originally the amounts suggested were about equal to the levels usually fed in trout hatcheries (Deuel et al. 1942). The feeding was later cut to half this amount, then raised again; recently it has been reduced to just slightly more than half of the normal feeding levels. In all cases it has been suggested that meat be fed at least once in 2 weeks as a change of diet, but the manufacturer of the pellets claims that meat is not necessary so far as growth and mortality are concerned. They further recommend the standard meat diet, with the gradual addition of 10 to 20 percent of small pellets, for fry. When the small pellets are added they are mixed with the meat, which gradually softens the pellets and forms a "mush"-type mixture. This is fed until the fish are 3 inches in length.

These pellets have been tested during the past 2 years with satisfactory results. There has been good growth, a satisfactory conversion, and a low mortality. No anemia has developed. The success of dry pellets in comparison to past failures with all-meal diets probably can be explained by the more complete consumption of the pellets and the reduction of the leaching of the nutrients into the water.

Because of the excellent results obtained by use of the pellets at the Cortland Experimental Hatchery and at other hatcheries in which they were tried, it was thought advisable to attempt pelleting our standard dry-feed mixtures in which the ingredients could be strictly controlled. In this manner a comparison could be drawn between the efficiency of our standard diet and the commercial mixtures.

Our first pelleted blend[1/] consisted of 25 percent each of dried skim milk, wheat flour middlings, and whitefish meal; 15 percent

1/ Experimental pellets were kindly furnished by the G. L. F. Marketing Service, Ithaca, New York.

cottonseed meal; and 10 percent dried brewer's yeast. Owing to the difficulty encountered in pelleting a mixture containing such a high level of dried milk, two other formulas were pelleted. In one the milk was decreased to 15 percent and the fish meal was increased to 35 percent. In the other formula the milk was removed and its percentage replaced by fish meal and 3 percent cod-liver oil. A third modification is now under test, consisting of 25 percent wheat flour middlings, 40 percent whitefish meal, 15 percent cottonseed meal, 10 percent dried brewer's yeast, 7 percent dried skim milk, and 3 percent cod-liver oil.

Preliminary experiments with the pellets of the above formulas have given results equal to those shown by the use of the commercial product. Further tests are now under way, and it is hoped that additional information as to the value of pellets may be obtained. Unfortunately, the accumulated pellet data have been confused by the different feeding levels suggested, the frequency of meat feedings, and changes in our own formulas. In spite of these difficulties, however, both our and the commercial pellet have given favorable results when compared to our standard diet, here at Cortland and at several State hatcheries.

In the formulation of our own pellets, progress has been slow, owing to the selection of ingredients which in a blended mixture would pellet easily and also insure the incorporation of foods considered necessary. The pellet without milk tends to powder (about 5 pounds of dust from 100 pounds). When a small amount of milk is added, this is reduced to approximately 1 pound per 100 pounds of pellets. The present mixture, in which 7 percent of dried skim milk is added and 3 percent of cod-liver oil is included, seems to satisfy the requirements of pelleting and has so far produced good results when fed to trout.

At current prices of ingredients in this area, the last formula mentioned (containing cod-liver oil and milk) costs from 9¢ to 11¢ per pound. The commercial mixture is selling for about 14¢ per pound. These costs are not excessive when they are compared to the cost of our production diet at 7⅛¢ per pound. It should be pointed out that much labor is saved in food preparation and the pellets are fed at a lower level than is the usual hatchery diet.

From the available data it is evident that future experiments should be designed for the determination of the most effective level of feeding, the necessity of feeding fresh meat, and the most efficient formula for pelleting.

There are several advantages to pellet feeding. When a pellet is swallowed, the fish receives the diet as compounded and in the relative proportions of the mixture. There is no great loss of the food in the water, either by leaching or by disintegration of the food. Pellets are fed as they are received, and the usual labor of food preparation is eliminated. Pellets limit the necessity for large meat storage facilities and cut the labor of grinding meat to a minimum. There is evidence that fish fed pellets are more even in size than fish fed the usual hatchery diets. Because pellets are fed at a lower percentage of the body weight, and because there is so little loss of ingredients during feeding, there appears to be a more complete consumption of the food. This results in less pollution of the water and, aside from the prevention of food wastage, reduces the labor that is needed for pond cleaning.

A few precautions should be mentioned when pellets are fed. The fish must be taught to eat pellets. In at least two instances the process was made easier by coating the pellets with a small amount of meat. In many cases the fish have taken the pellets readily without the addition of meat. Pellets should be fed slowly at first and not merely thrown into the pond. Upon changing to pellets, it has been noted that few are eaten after they reach the pond bottom. After a few days the trout will eat pellets off the bottom as readily as they at first hit them falling through the water.

Even with the most careful feeding practices, the results may not be too encouraging the first month; however, with the passage of time, the advantages of pellet feeding become increasingly evident. The data do not warrant the conclusion that pellets are the panacea for all fish feeding problems, but it is believed that they are, or may become, a good solution to at least a portion of the feeding problem of trout.

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REPRINTS

WHAT CAN FISH HEAR?

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Nothing, says one fisherman; heavy vibrations from footsteps, says another; even your voice, says a third. What does science have to say about it ... ? The answers again run the length of the scale. Many early investigators reported that fish could hear voices, ringing bells, whistles, gunshots, etc. Later investigators reported most species to be incapable of hearing anything. All of these studies lacked the modern equipment now available and most of them had failed to control such variables as intensity of the sound, sight of food or experimenter, etc. Even the best work, which proved that some species could hear certain sounds, was done without modern equipment.

In the present study, which was done in the summer of 1952 at The Pennsylvania State College under the supervision of Dr. William Lepley, modern acoustical equipment was used in an attempt to settle the argument. The study was made possible through the cooperation and help of the Pennsylvania Fish Commission through their Fisheries Research Laboratory at Bellefonte, Pa.

The fish used were bluegill sunfish (Lepomis machrochirus). These were chosen because of their small size, the relative ease of keeping them alive in an aquarium, their close relation to a game fish (black bass), and because they belong to a species which was definitely not supposed to be able to hear any frequency higher than 5,000 cycles per second.

The fish were placed in a 50-gallon aquarium. A wire feed cage was constructed that could be lowered into the tank in such a manner that a fish had to go look into it before it could tell whether there was any food in the cage. A variable frequency oscillator (a device for producing pure tones or frequencies) and a waterproofed earphone made up the sound equipment. The intensity was controlled by using a vacuum tube voltmeter to hold the voltage input constant.

When feeding time came, the feed cage was lowered into the aquarium--empty, if the sound was not turned on, and containing worms if the sound equipment was operating. A random order of feed and no-feed trials was followed so that the only clue the fish had as to whether there was anything in the feed box was whether or not they could hear the sound. The frequencies were varied in steps from 35 cycles per second to 17,920 cycles per second. All movements, time intervals, light conditions, etc., were held constant so that it all boiled down to one thing: if the fish were capable of learning, which they were, they should learn to come to the feed box only when the sound was turned on and stay away when it was turned off. Thus, when the point was reached where the fish stayed away but the sound equipment was actually on, it was plain that they were unable to hear this frequency.

After 112 feeding trials, the results showed that the sunfish could hear all steps from 35 cycles per second to 8,960 cycles per second, but could not hear 17,920 cycles per second.

Thus, these sunfish are perfectly capable of hearing many of the frequencies of human speech. Before anyone rushes out to buy a rubber boat or muzzles for his fishing companions, however, we should look at the matter of intensity. In this study the earphone was right in the water with the fish. Out on the stream conditions are far different. There is a great loss in intensity when sound passes from air to water, so that it would take a tremendous intensity, indeed, before the fish could hear a fisherman talking. Vibrations

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from a soggy stream bank or from a tacklebox dropped in the boat are something else again. Here the vibration is transmitted directly to the water and naturally the fish can hear it.

The thing to remember then is that intensity is the factor: if you get the vibrations into the water--no matter how--the fish can hear all about it.

CAN FISH SEE COLOR?

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The problem of color vision in game fishes is obviously a critical one for the user of artificial lures. The (at present) controversial status of this problem is due in most part to a difficulty inherent in any color vision study with animals: how can we be sure that the animal is responding to differences in color and not differences in intensity (brightness)? In the study just completed by the author at the Pennsylvania State College under the direction of Dr. William Lepley and with the cooperation of the Pennsylvania Fish Commission, Fisheries Research Laboratory, Bellefonte, Pennsylvania, an attempt was made to measure responses to color regardless of intensity.

The subjects of this experiment were Lepomis macrochirus, the bluegill sunfish. As any warm-water fisherman knows, this fish is closely related to the black bass so that results obtained on the bluegill could be generalized to the bass with high confidence.

The bluegills were kept in a fifty-gallon glass aquarium with an open wire box at each end. At feeding time, the lights in the room were extinguished and a beam of colored light was shot into each food box, one of red light, one of green. If a fish went into the box with the red illumination, he was fed a worm and the lights were turned out; if he went into the box with the green light, he was not fed and the lights were turned out. The lights were alternated randomly--sometimes the right-hand box got the red; sometimes, the green. The intensity factor was controlled by first equating the physical intensities of the two filters with a photometer. Then, because physical intensity does not necessarily correspond to biological intensity (that is, green may look much brighter than red of the same physical intensity to an animal which is completely color-blind), the intensities of both the red and the green were varied over a range of from one- to forty-five-foot candles. Thus, sometimes the red was as much as forty-five times as bright as the green, and sometimes vice versa. If the fish could tell the difference between the two lights, they must do so on the basis of wave length (color) alone.

Would the bluegills discriminate? They did. After one hundred practice trials, the bluegills chose red over green in a ratio of 94/7 in a series of 101 test trials.

Only one test remained to assure that the intensity factor had been ruled out. For this, two white filters were prepared so that instead of the red and green two white lights of varying intensity could be shot through the food boxes. If the fish were truly responding to differences in color and not in intensity, it would be predicted that they now either would not enter the food boxes at all or else would respond randomly--now going to the more highly illuminated box, now to the less illuminated one. They did respond randomly (16/12) in favor of the less illuminated, with two non-response trials.

On theoretical grounds, it seems highly likely that an animal with red-green color vision can discriminate the whole human spectrum, and possibly more. Red-green vision is seen as the last to develop as we go from the lower to the higher animals. So, unless some reader can pick out a flaw in this experiment, it can make a difference what color plug you lay alongside that lily pad or flick to the old log by the edge of the current. If that bass wants a fuschia-colored popper, you'd better have one!

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